

Low Cost Mission Operations Workshop

JPL

**Jet Propulsion Laboratory
Pasadena, California**

April 1994

Low Cost Mission Operations Workshop

Agenda

8:00 Welcome John R. Casani

8:10 Introduction

April 5: Gael F. Squibb

April 6: Esker K. Davis

April 7: Gael F. Squibb

8:20 Overview Gael F. Squibb

Mission Operations Element Briefings

9:00 Science Data Processing and Analysis William B. Green

10:00 Mission Design, Planning, and Sequencing Dr. Thomas W. Starbird

11:30 Lunch

12:30 Data Transport and Delivery Robert E. Edelson

13:30 Mission Coordination and Engineering Analysis Michael H. Hill

14:30 Summary Gael F. Squibb

15:30 Panel Discussion Gael F. Squibb,
Moderator

16:30 Unscripted Demos

18:00 End of Day

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OVERVIEW

Gael F. Squibb

**Manager: Flight Projects Mission Operations
Development Program Office**



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OUTLINE

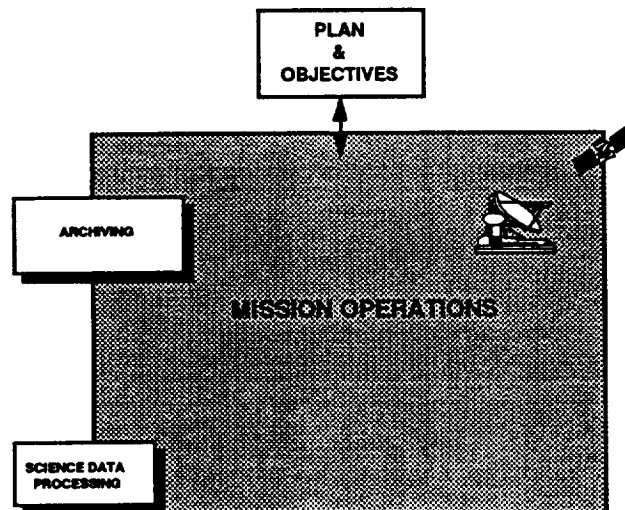
- ➔ • **DEFINITION OF MISSION OPERATIONS (OPS)**
- **MISSION OPERATIONS (MOS) ELEMENTS**
- **THE OPERATIONS CONCEPT**
- **MISSION OPERATIONS FOR TWO CLASSES OF MISSIONS**
 - **OPERATIONALLY SIMPLE**
 - **OPERATIONALLY COMPLEX**



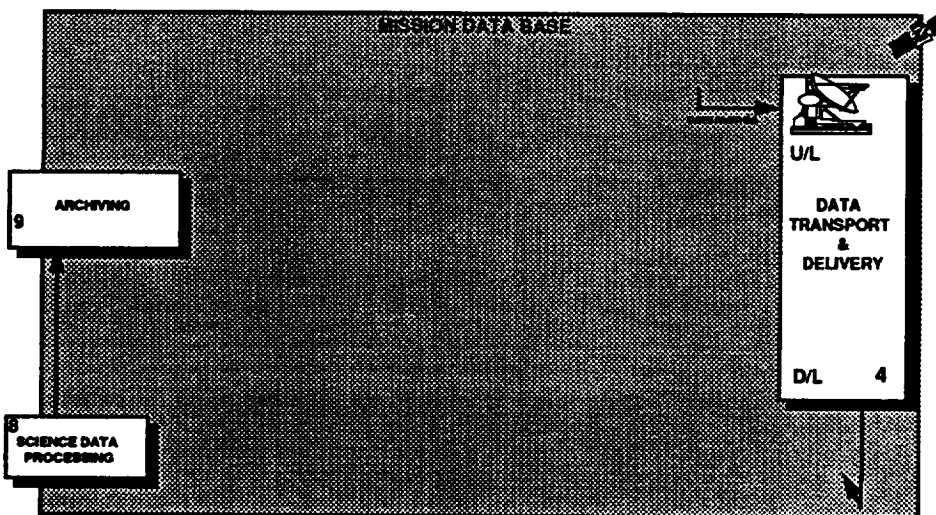
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- **A MISSION OPERATIONS SYSTEM IS COMPOSED OF:**
 - **THE GROUND DATA SYSTEM (GDS)**
 - **HARDWARE AND SOFTWARE LOCATED ON THE GROUND AND SOFTWARE LOCATED IN THE SPACECRAFT (S/C) USED TO**
 - **CONTROL THE SPACECRAFT AND SCIENCE INSTRUMENTS**
 - **PROCESS INFORMATION FROM THE SPACECRAFT AND SCIENCE INSTRUMENTS**
 - **THE OPERATIONS ORGANIZATION**
 - **THE PEOPLE AND PROCEDURES USED TO**
 - **CONTROL THE SPACECRAFT AND SCIENCE INSTRUMENTS**
 - **PROCESS INFORMATION FROM THE SPACECRAFT AND SCIENCE INSTRUMENTS**



- **TWO MAJOR PROCESSES**
 - UPLINK PROCESS (U/L)
 - DOWNLINK PROCESS (D/L)
- **THESE PROCESSES ARE LINKED TOGETHER**
 - ON ONE END WITH THE DATA TRANSPORT AND DELIVERY SYSTEM THAT IS USED TO COMMAND THE SATELLITE AND TO RECEIVE ITS TELEMETRY
 - THE RECEIVED DATA OFTEN CHANGES THE MISSION PLAN AND/OR SEQUENCES



OUTLINE

- DEFINITION OF MISSION OPERATIONS (OPS)
- ➔ • MISSION OPERATIONS (MOS) ELEMENTS
- THE OPERATIONS CONCEPT
- MISSION OPERATIONS FOR TWO CLASSES OF MISSIONS
 - OPERATIONALLY SIMPLE
 - OPERATIONALLY COMPLEX



- NINE GENERIC ELEMENTS DESCRIBE THESE PROCESSES
 - FIVE OF THESE NINE ELEMENTS DEAL WITH BOTH THE UPLINK AND DOWNLINK PROCESSES
- NOTE: TODAY'S USER IS, OR MAY BE, INVOLVED IN NEARLY EVERY ASPECT OF OPERATIONS, SO WE NO LONGER SHOW A USER / SCIENTIST BOX OR ELEMENT





THE NINE MISSION OPERATIONS ELEMENTS

1. MISSION PLANNING
2. SEQUENCE DEVELOPMENT
3. MISSION CONTROL
4. DATA TRANSPORT AND DELIVERY
5. NAVIGATION
6. SPACECRAFT (S/C) PLANNING AND ANALYSIS
7. SCIENCE PLANNING AND ANALYSIS
8. SCIENCE DATA PROCESSING
9. ARCHIVING

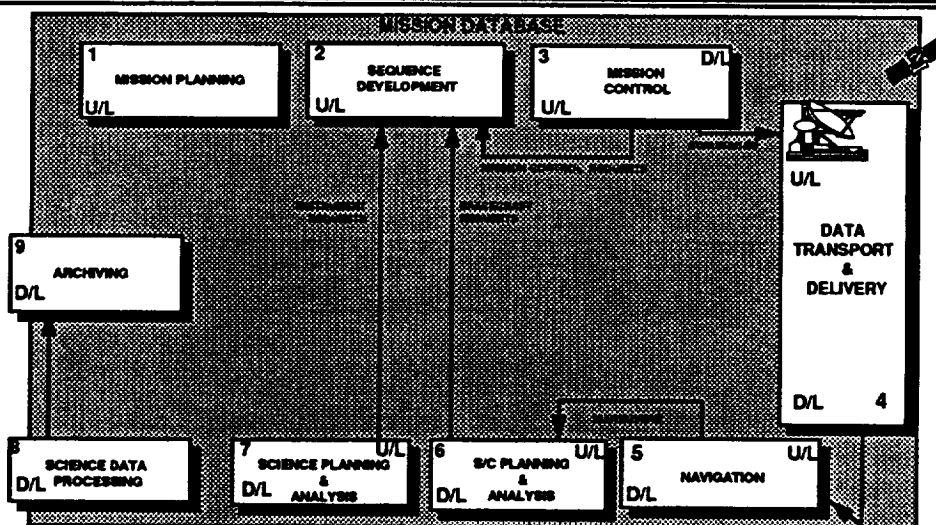


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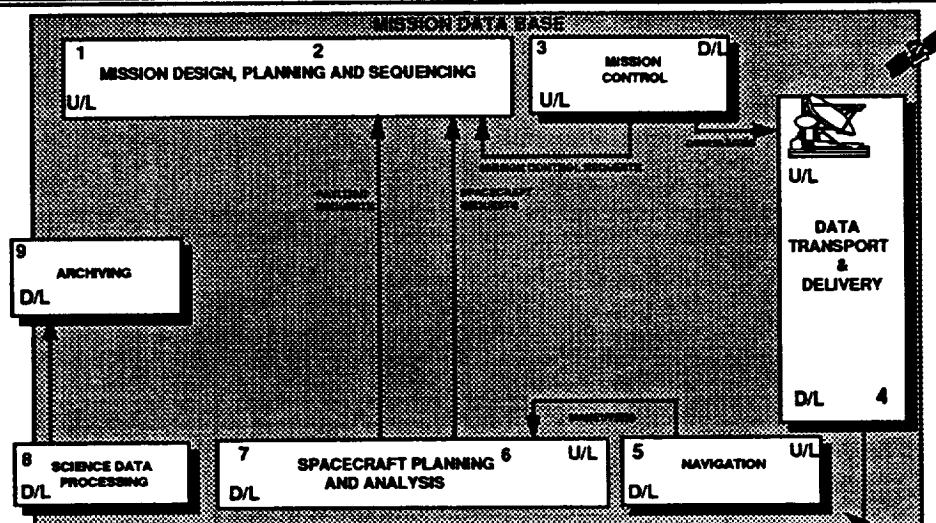
SYSTEM OVERVIEW



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- THE ELEMENTS CAN BE COMBINED DEPENDING ON
 - THE COMPLEXITY OF THE MISSION
 - THE SPACECRAFT
 - THE INSTRUMENT
- COMBINING ELEMENTS CAN TAKE PLACE IN THE GROUND DATA SYSTEM, THE OPERATIONS ORGANIZATION, OR BOTH
- CURRENT MISSIONS ARE COMBINING THE NINE ELEMENTS INTO A SYSTEM THAT PERFORMS THE SAME FUNCTIONS, BUT WITH FEWER ELEMENTS
 - STAFF ARE PERFORMING MULTIPLE FUNCTIONS, CROSSING TRADITIONAL ORGANIZATIONAL BOUNDARIES
- VOYAGER AND MARS PATHFINDER BOTH HAVE OPERATIONS ORGANIZATIONS WITH TWO TEAMS



- **FOR EACH OF THE NINE ELEMENTS**
 - **INPUT, FUNCTION, AND OUTPUT CHARTS ARE INCLUDED AT THE END OF THIS PRESENTATION**
- **THESE CHARTS ARE A BASIC CHECKLIST TO ENSURE THAT A MISSION HAS INCLUDED ALL OPERATIONS PROCESSES REQUIRED**



INPUTS	FUNCTIONS	OUTPUTS
PLAN OR MODIFIED PLAN	PRE-LAUNCH VERIFY CAPABILITY TO GENERATE FLIGHT SEQUENCES GENERATE HIGH ACTIVITY / CRITICAL PERIOD SEQUENCES AND TEST ON FLIGHT SYSTEM SOMETIMES USED TO GENERATE SYSTEM INTEGRATION AND TEST SEQUENCES POST-LAUNCH INTEGRATION OF MISSION PHASE PLAN WITH CURRENT REQUESTS FROM MISSION CONTROL SPACECRAFT AND INSTRUMENT TEAMS INSTRUMENT AND SPACECRAFT PARAMETER GENERATION DETAILED SEQUENCE GENERATION VALID COMMANDS MISSION RULE CHECKS TIMELINE GENERATION SEQUENCE REVIEW AND APPROVAL SIMULATION OF SOME SEQUENCES SYSTEM & SUBSYSTEM ANALYSIS OF SEQUENCE COMMAND LOAD PRODUCT GENERATION PLANNED REAL-TIME COMMAND GENERATION AS-FLOWN SEQUENCE OF EVENTS GENERATION	DETAILED SEQUENCES TIMELINES COMMAND LOAD
MISSION RULES		
FLIGHT RULES		
MISSION PHASE PLAN		
SEQUENCE REQUESTS MISSION CONTROL SPACECRAFT INSTRUMENT		



- THE FOLLOWING DISCUSSION ALONG WITH THE ELEMENT PRESENTATIONS WILL SHOW APPROACHES WHICH WILL LEAD TO A LOW COST MISSION OPERATIONS SYSTEM
- MARS PATHFINDER HAS FOLLOWED MOST OF THESE CONCEPTS
- THE TOTAL DEVELOPMENT COST FOR THE GROUND DATA SYSTEM
 - \$5.9 MILLION
 - APPROXIMATELY 4% OF THE \$150 MILLION DEVELOPMENT COST
 - PAST MISSIONS HAVE SPENT 10% TO 15%



- OPERATIONS CONCEPT INPUT ATTRIBUTES



OUTLINE

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- **MISSION OPERATIONS FOR TWO CLASSES OF MISSIONS**
 - **OPERATIONALLY SIMPLE**
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**WHAT MUST THE ELEMENTS DO
FOR A GIVEN MISSION**

- **THE OPERATIONS CONCEPT ENABLES A MISSION TO MINIMIZE LIFE CYCLE COSTS**
- **DEVELOPING AN OPERATIONS CONCEPT IS A PROCESS THAT INVOLVES MULTIPLE DISCIPLINES, WORKING TOGETHER TO DESCRIBE (IN THE SYSTEM USER'S TERMS) THE OPERATIONAL ATTRIBUTES OF ALL ELEMENTS OF THE SYSTEM**



ATTRIBUTES

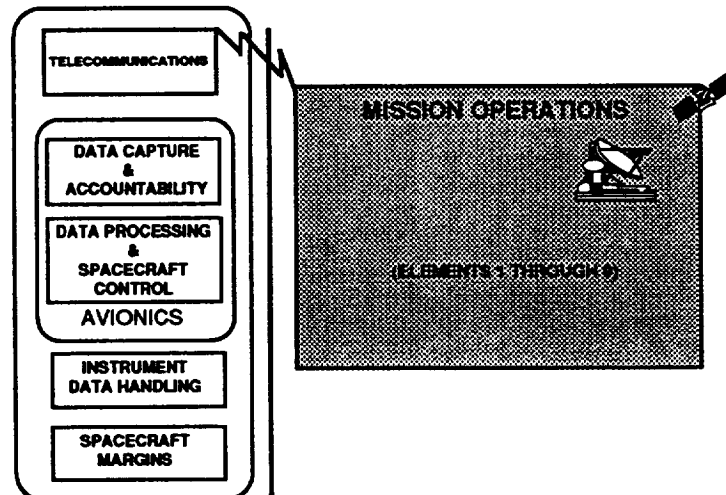
- **STRESSES THE WAY THE SYSTEM WILL BE OPERATED AND USED (OPERATIONAL CHARACTERISTICS) AND IN TERMS THAT ARE UNDERSTOOD BY THE OPERATORS OF THE SYSTEM AND THE RECIPIENTS OF THE DATA FROM THE SYSTEM**
- **FOCUSES ON AREAS THAT ARE**
 - NOT UNDERSTOOD
 - CONTROVERSIAL
 - DRIVERS FOR THE SYSTEM
- **FOSTERS A COMMON UNDERSTANDING OF PROCESSES AMONG DIVERSE ELEMENTS OF A PROJECT**



AN OPERATIONS CONCEPT CONSIDERS BOTH FLIGHT & GROUND ELEMENTS

FLIGHT SEGMENT

GROUND SEGMENT



OPERATIONS CONCEPT INPUTS

MISSION SCOPE,
OBJECTIVES, AND
SCIENCE REQUIREMENTS

MISSION PLAN

PROGRAMMATIC

MISSION PHILOSOPHIES,
STRATEGIES, & TACTICS

INSTRUMENT
CHARACTERISTICS

SPACECRAFT
CHARACTERISTICS

END-TO-END INFORMATION
SYSTEM (EIS)
CHARACTERISTICS

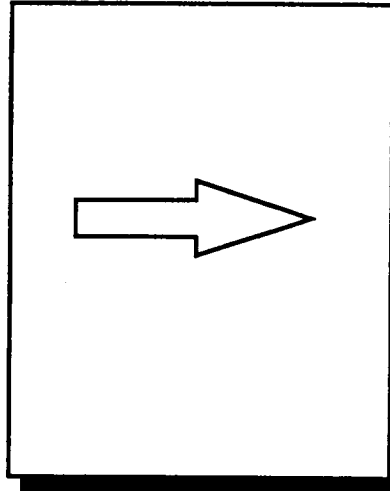
GROUND SYSTEM
CHARACTERISTICS

END USER'S DATA
PRODUCT DEFINITION



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PROCESS



OUTPUTS

OPERATIONAL
SCENARIOS

DATA FLOW
DIAGRAMS

TIMELINES

ORGANIZATION
AND TEAM
RESPONSIBILITIES

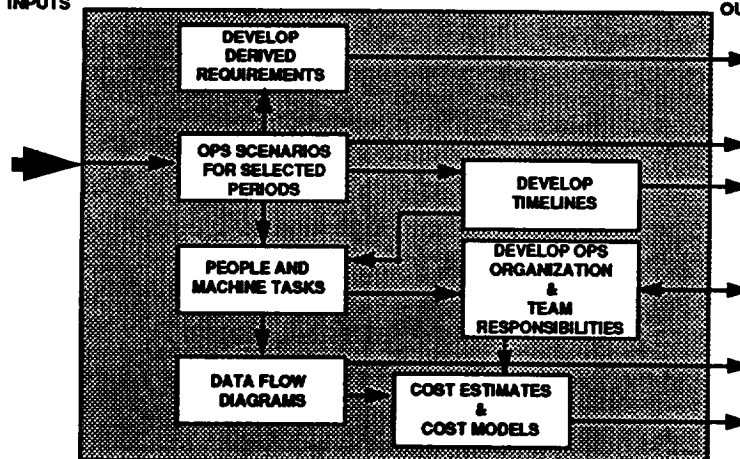
REQUIREMENTS AND
DERIVED REQUIREMENTS

COST FOR A GIVEN
SET OF INPUTS

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THE PROCESS

INPUTS

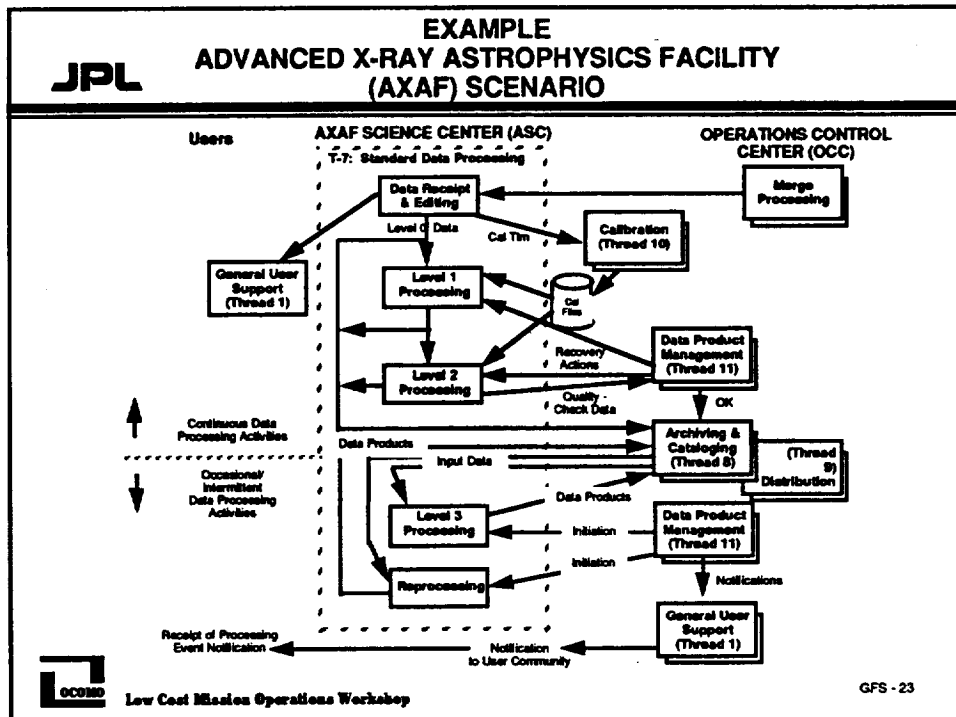


OUTPUTS

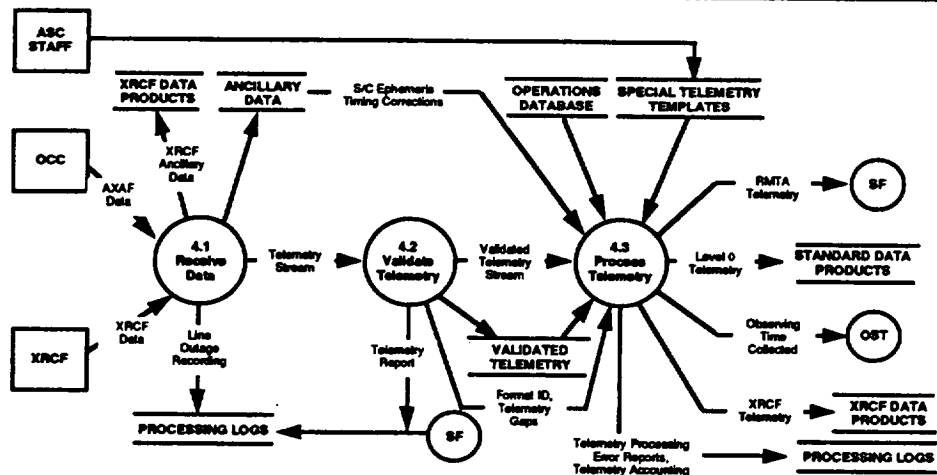


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EXAMPLE AXAF DATA FLOW DIAGRAM



OVERVIEW

OUTLINE

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AN OPERATIONALLY SIMPLE MISSION

MISSION SCOPE, OBJECTIVES, AND SCIENCE REQUIREMENTS

- THE PURPOSE OF THIS MISSION IS TO STUDY THE PROPERTIES OF THE SOLAR WIND FOR A PERIOD OF TWO YEARS, FROM A LOCATION OUTSIDE THE EARTH'S BOW SHOCK
- A HALO ORBIT ABOUT THE L1 EARTH-SUN LIBRATION POINT WAS SELECTED TO MEET THAT MINIMUM REQUIREMENT, WHILE MINIMIZING COMMUNICATIONS REQUIREMENTS AND TRAJECTORY COMPLEXITY
- THE INSTRUMENTS MUST FACE INTO THE AVERAGE DIRECTION OF ARRIVAL OF THE SOLAR WIND RELATIVE TO THE SPACECRAFT, WHOSE 30 km/s MOTION PERPENDICULAR TO THE SOLAR RADIUS DIRECTION CANNOT BE IGNORED; THIS LEADS TO THE REQUIREMENT THAT THE SPACECRAFT SPIN AXIS POINT 4° AHEAD OF THE SUN



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AN OPERATIONALLY COMPLEX MISSION

MISSION SCOPE, OBJECTIVES, AND SCIENCE REQUIREMENTS

- THE PURPOSE OF THIS MISSION IS TO RENDEZVOUS WITH A SHORT-PERIOD COMET, TO STUDY ITS SURFACE MORPHOLOGY AND COMPOSITION WITH REMOTE-SENSING INSTRUMENTS, AND THEN TO GRAB A SAMPLE OF SURFACE MATERIAL FOR ANALYSIS ONBOARD THE SPACECRAFT
- IT IS ASSUMED THAT THE ONLY WAY TO RENDEZVOUS WITH THE TARGET, GIVEN THE AVAILABLE LAUNCH VEHICLES FOR THE MISSION, IS VIA DELTA VEGA TRAJECTORIES
- IT IS FURTHER ASSUMED THAT THE BODY IS SMALL AND IRREGULAR, ITS SPIN VECTOR IS NOT KNOWN, AND ITS EPHEMERIS IS NOT WELL KNOWN *A PRIORI*
- FURTHERMORE, THE FICTITIOUS COMET IS KNOWN TO BE WEAKLY AND IRREGULARLY ACTIVE, SO CERTAIN SAFEGUARDS (OR RETREAT STRATEGIES) MUST BE BUILT INTO THE SCENARIO FOR THE CLOSE APPROACH REQUIRED TO GET THE SAMPLE



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MISSION PLAN

COMPLEX

SIMPLE

Single Fixed Launch Period requires MORE contingency / reserves to ensure launch readiness of MOS.

vs.

Flexible Launch Period

Characteristic determination of primary target to achieve mission objectives

vs.

Data Collection Mission

Site selection required to achieve mission objectives

- Data analysis leads to new sequences

vs.

Data Collection Mission

Optical Navigation required to achieve/ follow mission plan

- Additional sequences and analysis

vs.

Angles and Doppler

Automated (onboard) target acquisition required

- Additional development costs and operations testing / maintenance

vs.

Data Collection Mission



PROGRAMMATIC

Assumed the same programmatic guidelines



MISSION PHILOSOPHIES, STRATEGIES, AND TACTICS

Assumed same mission philosophies, strategies, and tactics

**INSTRUMENT CHARACTERISTICS****COMPLEX**

Instrument pointing required

- Planning software
- Sequencing software
- Pointing reconstruction software

vs.

SIMPLE

Spinner, no instrument pointing requirements

Spacecraft pointing control and stability requirements

- Calibration sequences and analysis

vs.

Spinner

Instrument control by ground-generated sequences

- Sequence generation and validation capabilities required

vs.

Autonomous instrument mode changes



SPACECRAFT CHARACTERISTICS

COMPLEX

SIMPLE

Pointing control and stability
- See Instrument Characteristics slide

vs. Spinner

Margins

- Zero to negative margins
 - Sequence validation at subsystem level
 - Manpower and software costs
- High-gain X-band
 - Pointing required for dumps
 - Data mode changes for weather
 - Increased sequence complexity
- Data rate requirements
 - Multiple selectable to maximum data return

vs. Positive margins

vs. Low-gain S-band

vs. Single fixed

Subsystem Interactions

- Multiple interactions

vs. Positive margin and no interaction



**END-TO-END INFORMATION SYSTEM (EEIS) CHARACTERISTICS:
UPLINK**

COMPLEX

SIMPLE

Spacecraft conformity to MOS existing interface and command capabilities
- Allows use of existing capabilities

vs. New concepts not yet implemented in MOS

Instrument generation capabilities greater than recorder storage capabilities for one week
- Most monitor recorder storage state and/or require more tracking resources

vs. Positive margin

Sequences determined from data closed loop process
- Time criticality function of mission plan

vs. Data collection and analysis mission

Margin analysis required

vs. Positive margin



**END-TO-END INFORMATION SYSTEM (EEIS) CHARACTERISTICS:
DOWNLINK****COMPLEX****SIMPLE**

Conform to CCSDS standards
– Allows use of existing MOS
capabilities

vs.

Same

Margin analyses required

vs.

Positive margin

Health and safety based on
predicts

vs.

Predicts not required since
sequences will not drive health
and safety

**GROUND SYSTEM CHARACTERISTICS****COMPLEX****SIMPLE**

Spacecraft compatibility with
ground system capabilities and
interfaces

vs.

Same

Navigation accuracy requiring
specialized sequences and data
gathering

vs.

Simple navigation process

Sequencing complexity

vs.

Simple or autonomous
sequencing



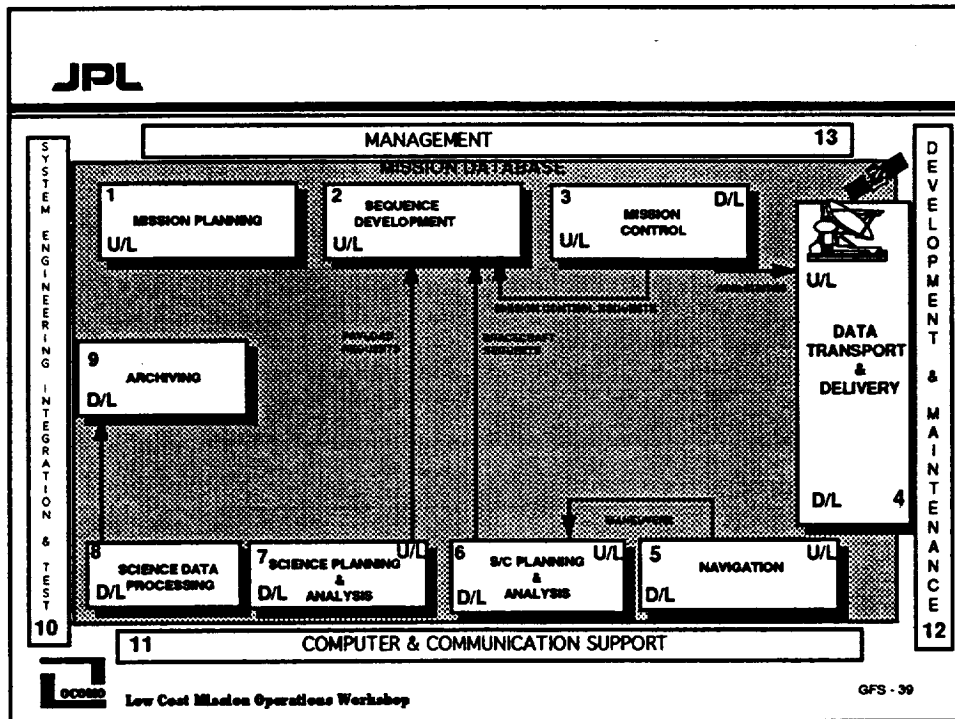
END USER'S DATA PRODUCT DEFINITION

- Similar requirements for both
- Nothing special
- No drivers that exceed MOS capabilities



- **FOUR ADDITIONAL ELEMENTS NEED TO BE CONSIDERED FOR THE SUCCESSFUL DEVELOPMENT, IMPLEMENTATION, AND OPERATION OF A MISSION OPERATION SYSTEM, WHICH ARE NOT DISCUSSED TODAY**
 - **SYSTEM ENGINEERING, INTEGRATION, AND TEST**
 - **COMPUTERS AND COMMUNICATION SUPPORT**
 - **DEVELOPMENT AND MAINTENANCE**
 - **MANAGEMENT**





JPL

ELEMENT BRIEFINGS

SCIENCE DATA PROCESSING MOS Elements 8 and 9	William B. Green
MISSION PLANNING and SEQUENCING MOS Elements 1 and 2	Dr. Thomas W. Starbird
MISSION DATA TRANSPORT and DELIVERY MOS Element 4	Robert Edelson
MISSION COORDINATION and ENGINEERING ANALYSIS MOS Elements 3, 5, 6, and 7	Michael H. Hill

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- **THE ELEMENT BRIEFINGS AND THE ASSOCIATED DEMONSTRATIONS WILL:**
 - **DISCUSS MULTIMISSION SOFTWARE CAPABILITIES**
 - **ADAPTATION REQUIRED FOR A SPECIFIC MISSION**
 - **OPERATIONS SERVICES AVAILABLE**
- **THE THEMES OF THESE ELEMENT BRIEFINGS**
 - **JPL HAS THE ABILITY TO IMPLEMENT AND OPERATE A MISSION OPERATIONS SYSTEM FOR A MISSION**
 - **THE CAPABILITIES FOR MANY OF THE MISSION OPERATIONS ELEMENTS MAY BE DELIVERED TO A P.I. FOR USE AT HIS/HER LOCATION**
 - **THE P.I. MAY PERFORM A FUNCTION AT HIS/HER LOCATION AND INTERFACE WITH JPL CAPABILITIES BY COMPLYING WITH INTERFACE DEFINITIONS**



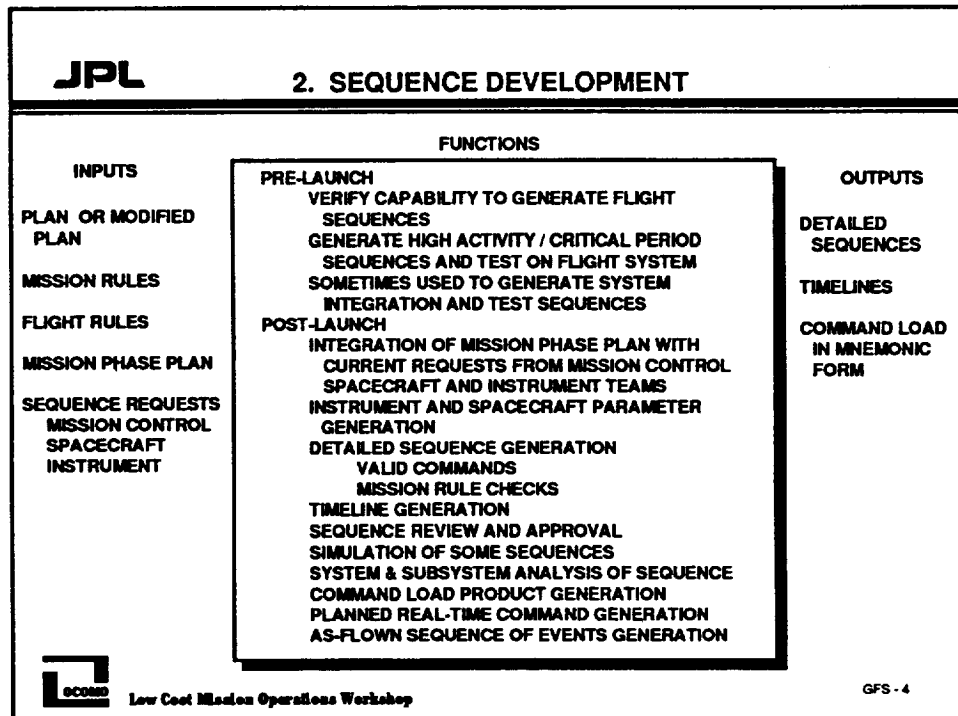
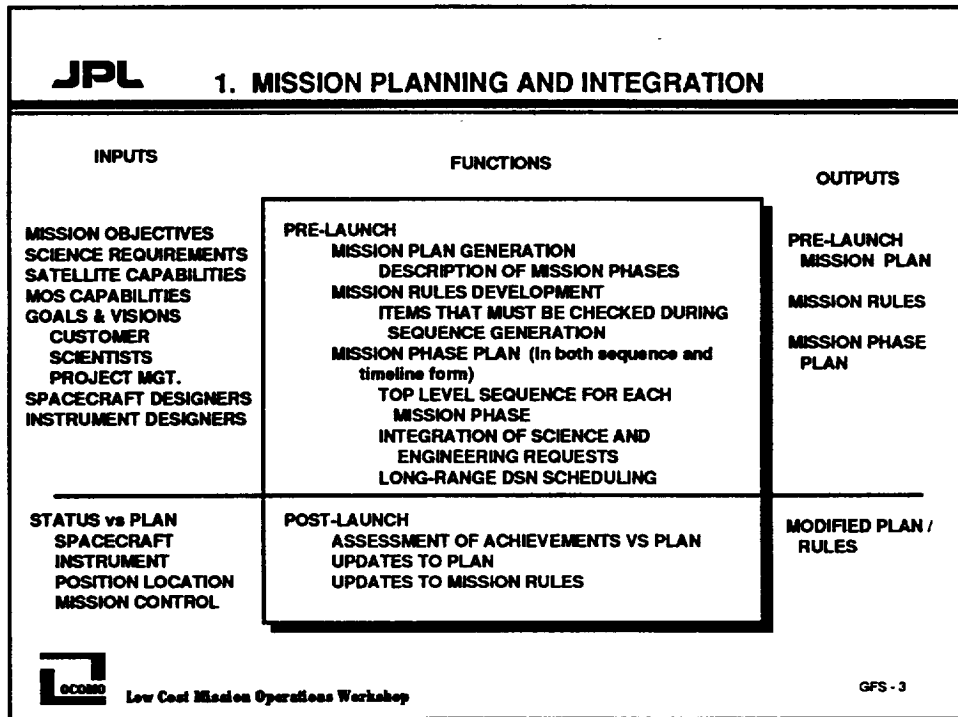
DETAILED INFORMATION NOT PRESENTED



THE 13 MOS ELEMENTS

1. **Mission Planning and Integration**
2. **Sequence Development**
3. **Mission Control**
4. **Data Transport and Delivery**
5. **Navigation**
6. **Spacecraft Planning and Analysis**
7. **Science Planning and Analysis**
8. **Science Data Processing**
9. **Archiving and Mission Database**
10. **System Engineering Integration and Test**
11. **Computers and Communication Support**
12. **Development and Maintenance**
13. **Management**







3. MISSION CONTROL

INPUTS

PLANS
SEQUENCES
LIMITS
SPACECRAFT
INSTRUMENT
POSITION LOCATION
COMMAND FILES
REAL-TIME DATA
TELEMETRY
GROUND DATA
SYSTEM (GDS)
MONITOR

FUNCTIONS

PRE-LAUNCH
PREPARE BASELINE PROCEDURES
VALIDATE REAL-TIME CAPABILITIES
COMMAND
TELEMETRY
ALARM CHECKING
VALIDATE CAPABILITY TO CONFIGURE, CONTROL,
AND MONITOR THE GROUND SYSTEM
SUPPORT INTEGRATION & TEST
POST-LAUNCH
UPLINK
CONVERSION OF MNEMONICS TO BINARY CMDS
REAL-TIME PASS SUPPORT
R/T COMMANDS
COMMAND LOADS
DOWNLINK
HEALTH & SAFETY MONITORING
TELEMETRY MEASUREMENTS VS ALARMS
ONBOARD MEMORY READOUT AND
VERIFICATION
COORDINATION
SHORT-TERM DSN SCHEDULING
GENERATION OF INTEGRATED FLIGHT/GRD SEQ
MONITOR / CONTROL R/T GROUND DATA SYSTEM
COORDINATE INSTITUTIONAL SUPPORT
VALIDATE CONFIGURATION & MONITOR
PERFORMANCE

OUTPUTS

PASS REPORTS
ALARMS
SPACECRAFT
INSTRUMENT
POSITION
INTEGRATED
SEQUENCE OF
EVENTS



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4. DATA TRANSPORT AND DELIVERY

INPUTS

ANTENNA PREDICTS
BINARY COMMANDS
GROUND SEQUENCES
R/F PREDICTS

FUNCTIONS

PRE-LAUNCH
TEST AND VALIDATE FACILITIES
PARTICIPATE IN END-TO-END TESTS WITH
SPACECRAFT AND INSTRUMENTS TO VALIDATE
UPLINK AND DOWNLINK FUNCTIONS

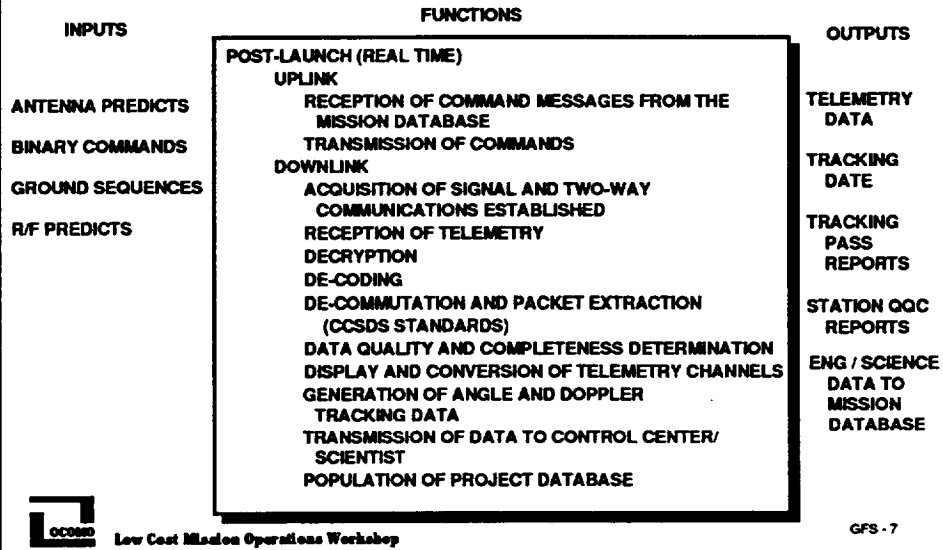
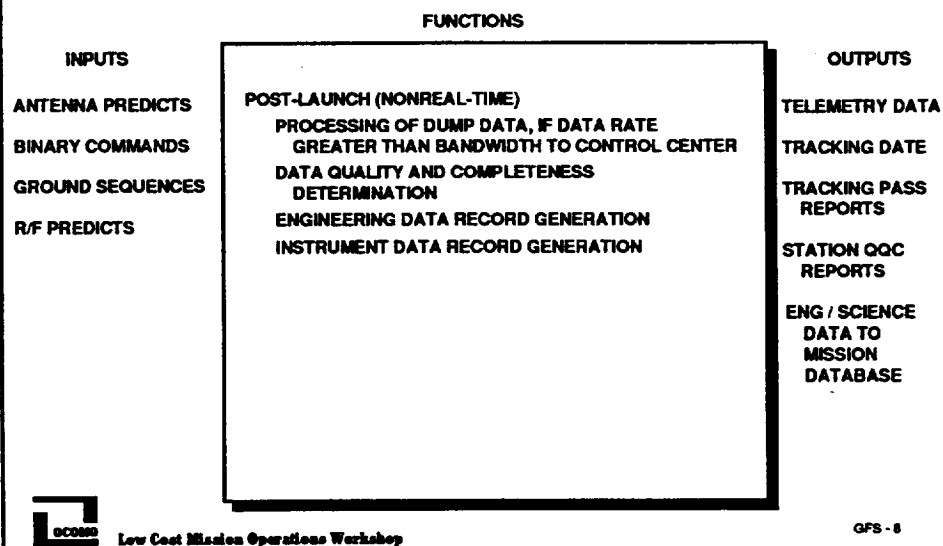
OUTPUTS

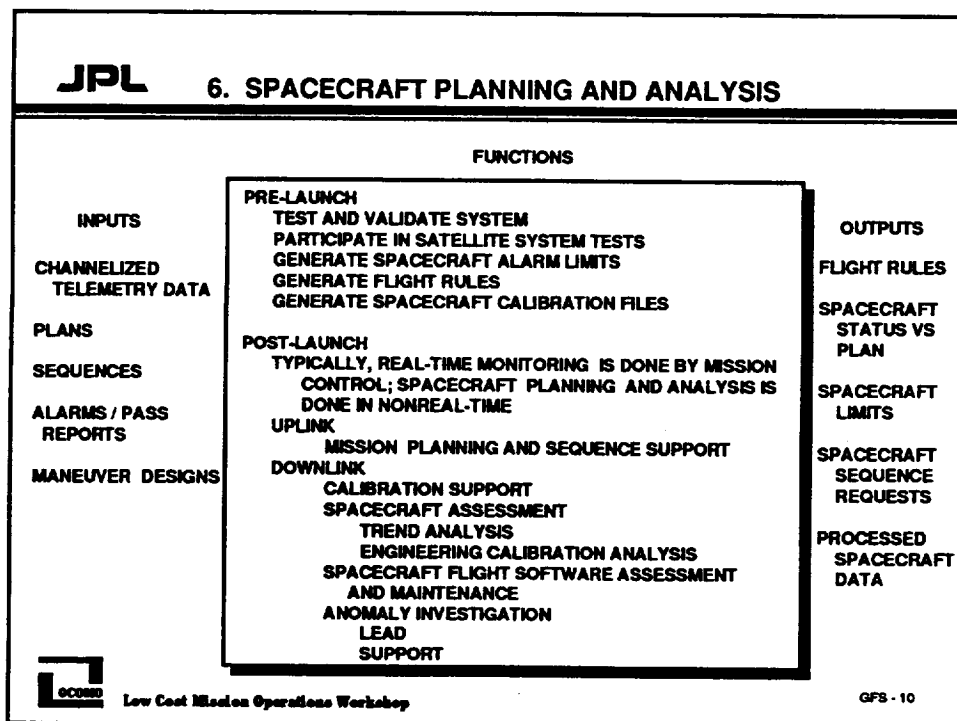
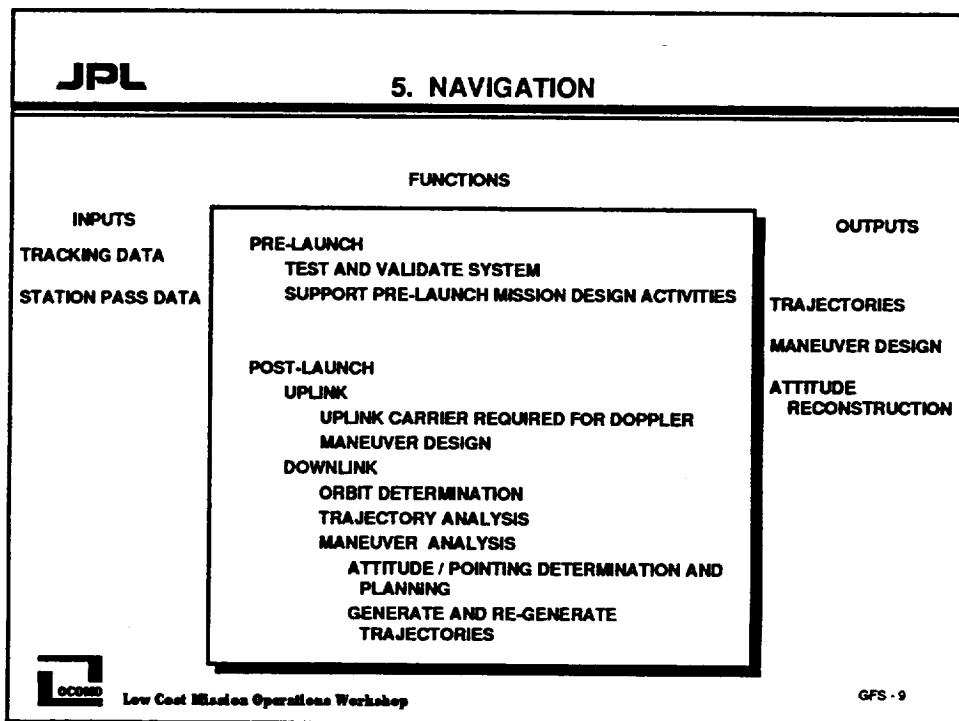
TELEMETRY DATA
TRACKING DATE
TRACKING PASS
REPORTS
STATION QQC
REPORTS
ENG / SCIENCE
DATA TO
MISSION
DATABASE



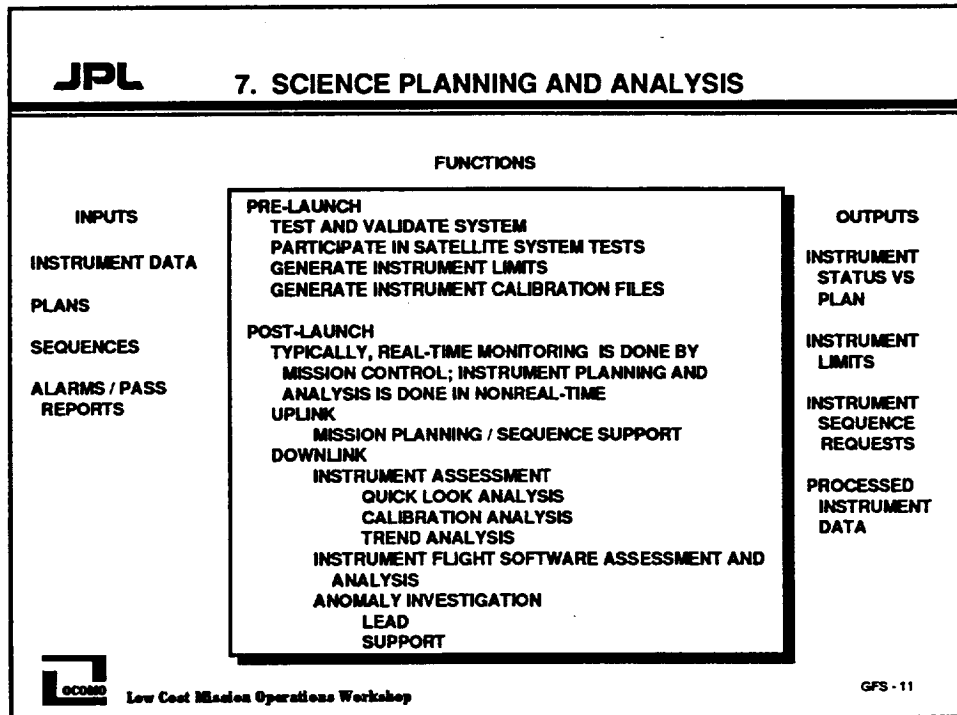
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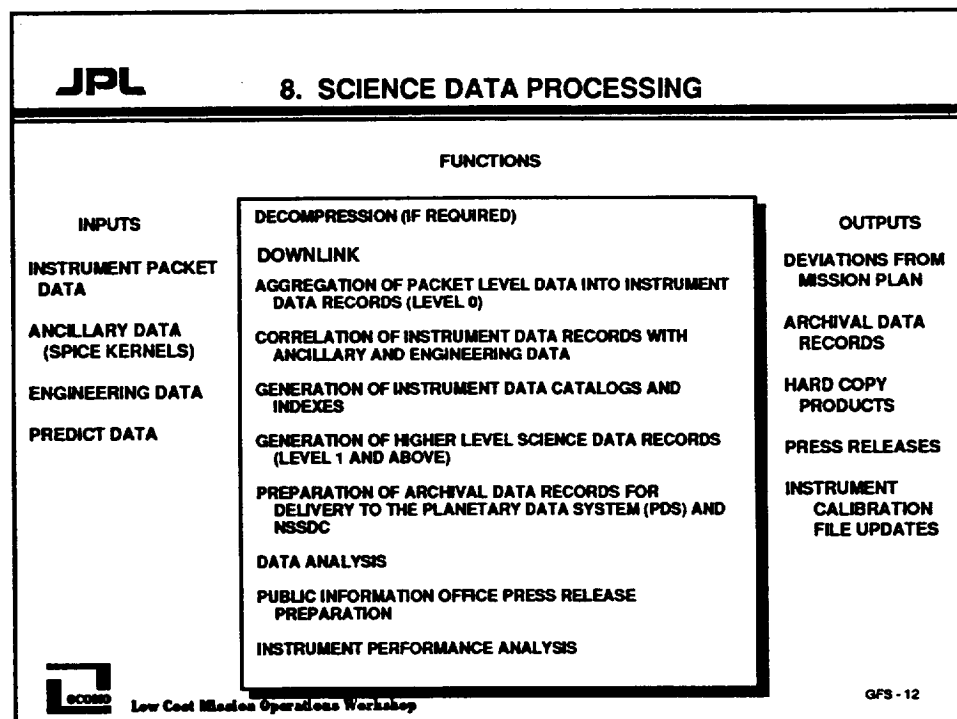
4. DATA TRANSPORT AND DELIVERY**4. DATA TRANSPORT AND DELIVERY**



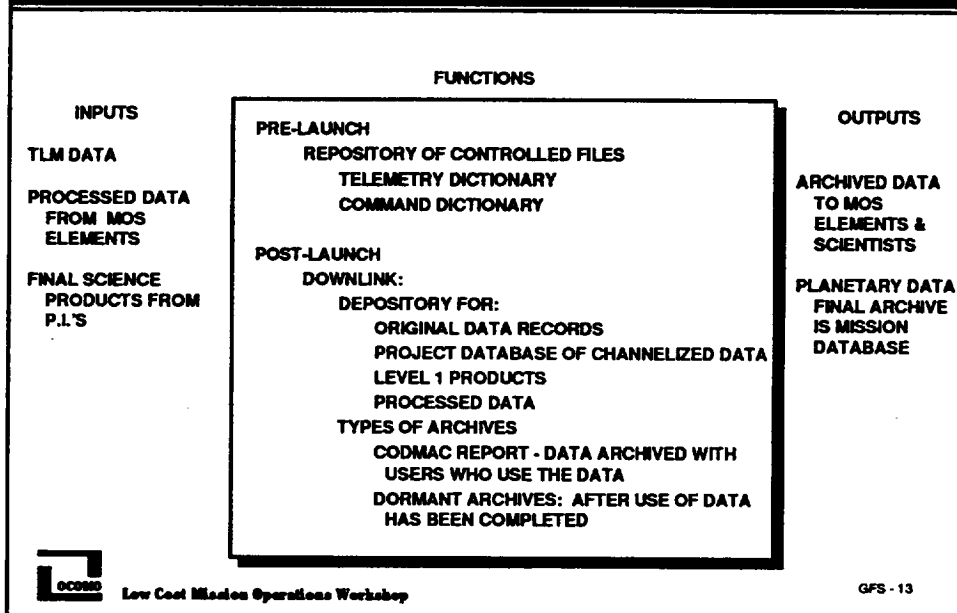
7. SCIENCE PLANNING AND ANALYSIS



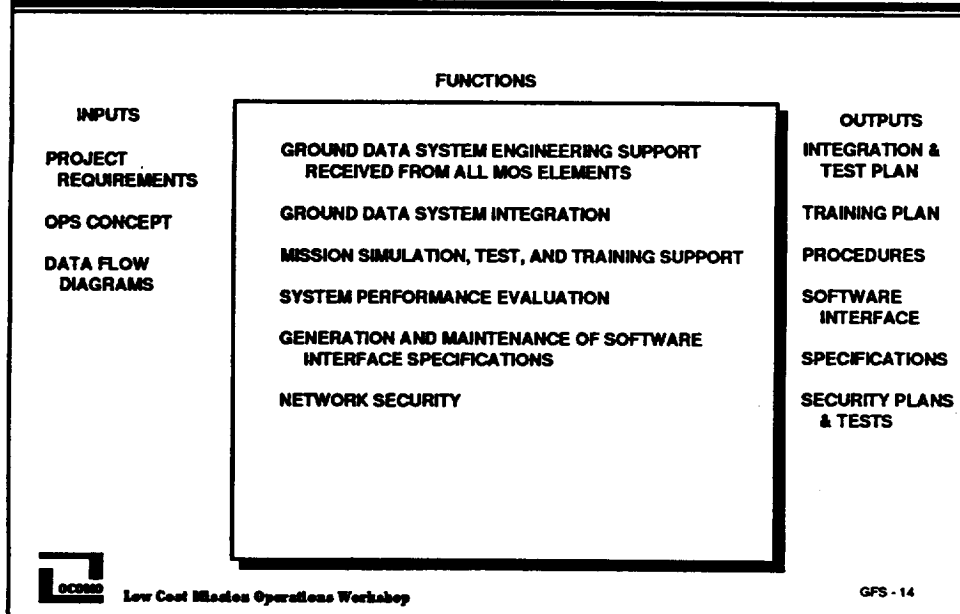
8. SCIENCE DATA PROCESSING



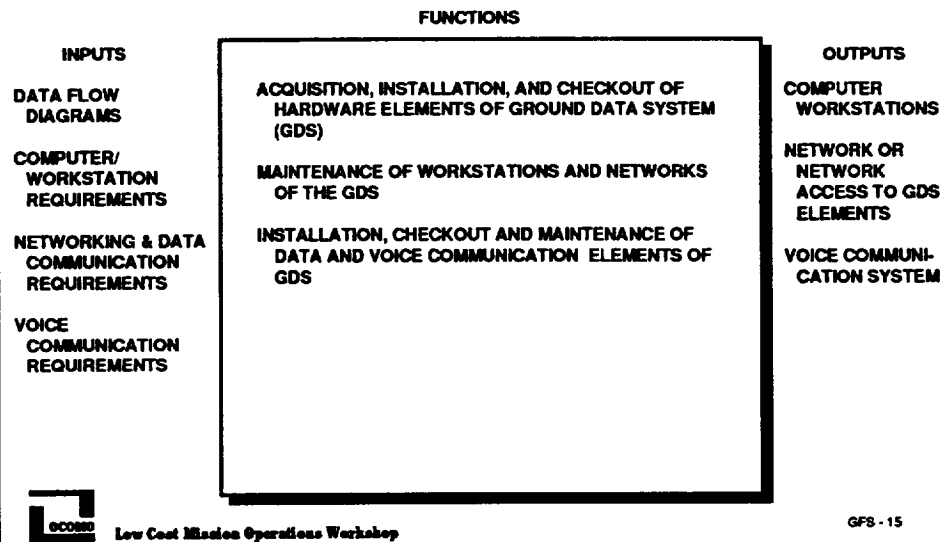
9. ARCHIVING AND MISSION DATABASE



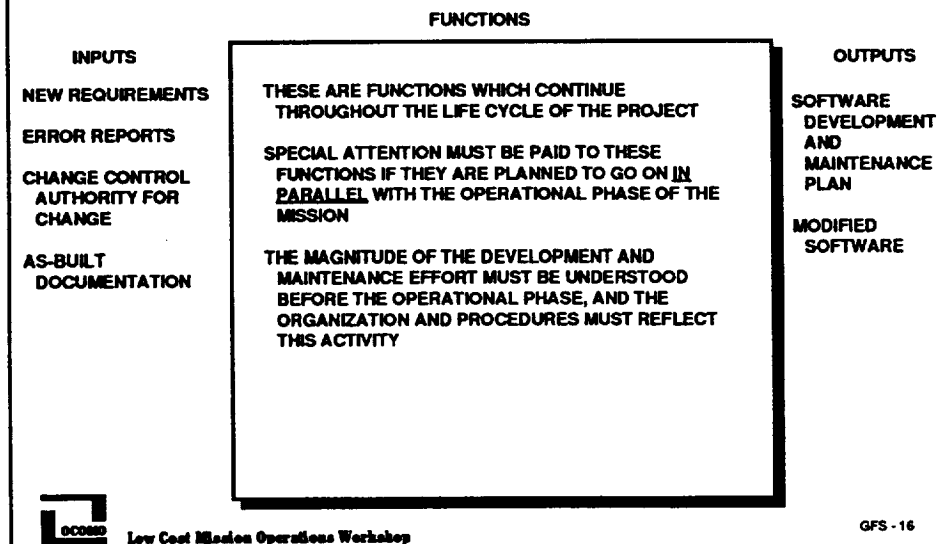
10. SYSTEM ENGINEERING INTEGRATION AND TEST



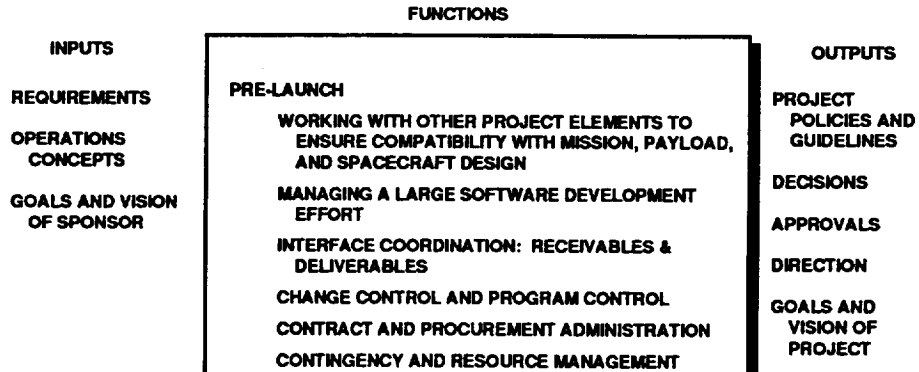
JPL 11. COMPUTERS AND COMMUNICATION SUPPORT



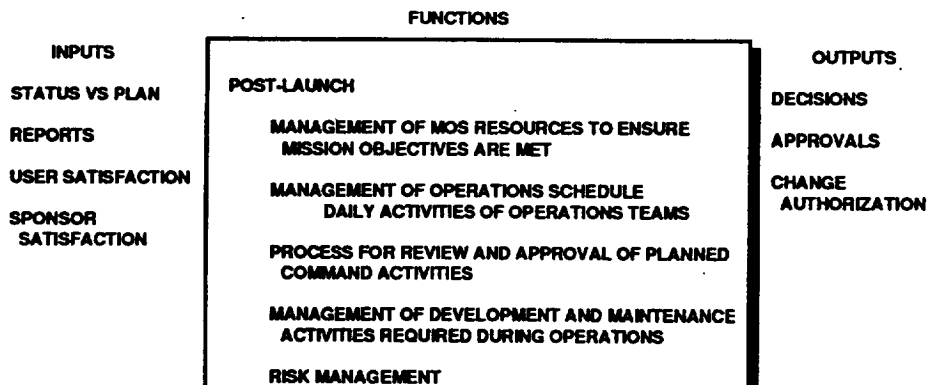
JPL 12. DEVELOPMENT AND MAINTENANCE



13. MANAGEMENT



13. MANAGEMENT (continued)



- INPUT CHARACTERISTICS ARE GIVEN ON THE FOLLOWING PAGES

**MISSION SCOPE, OBJECTIVES, AND SCIENCE REQUIREMENTS**

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AN OPERATIONALLY COMPLEX MISSION

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AN OPERATIONALLY SIMPLE MISSION

MISSION PLAN

- LAUNCH VEHICLE = DELTA 2
- LAUNCH DATE = FLEXIBLE
- MISSION DURATION = 2 YEARS + 107 DAYS
- TRAJECTORY & MANEUVER CHARACTERISTICS
 - 107 DAYS TRANSFER ORBIT TO L1
 - 65 M/SEC DELTA V FOR NAVIGATION TO ORBIT INSERTION
 - TWO LOOPS AROUND HALO PER YEAR
 - MAINTENANCE MANEUVERS EVERY 8 WEEKS
 - DELTA V FOR MAINTENANCE 35 M/SEC
- ORBIT DETERMINATION
 - DOPPLER & RANGING
 - CONTINUOUS L > L+ 2 WEEKS
 - CRUISE 1/WEEK
 - INSERTION - 2 WEEKS > +1 WEEK
 - 1 PASS PER DAY
 - 24 HOURS CONTINUOUS DURING ORBIT INSERTION
- LIGHT TIME TO L1 IS > BURN TIME



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AN OPERATIONALLY COMPLEX MISSION

MISSION PLAN

- LAUNCH VEHICLE = DELTA 7925
- LAUNCH DATE = 15 DAY WINDOW
- MISSION DURATION = 7 YEARS
- TRAJECTORY AND MANEUVER CHARACTERISTICS
 - DEEP SPACE MANEUVER, 0.5 km/s
 - EARTH FLYBY, 300 km ALTITUDE L+2 YRS
 - DEEP SPACE MANEUVER AT 4AU 2.0 km/s
 - ACQUIRE TARGET
 - APPROACH FROM DARK SIDE, SEE ONLY THE CRESCENT
 - RENDEZVOUS BURN AT 1.3 AU 0.8 km/s AT L+6 YEARS
 - SLOW FLYBYS TO DETERMINE MASS AND ROTATION OF BODY



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AN OPERATIONALLY COMPLEX MISSION

MISSION PLAN (continued)

- ORBIT THE NUCLEUS FOR 1 YEAR
 - APHELION A 4 AU; PERIHELION AT 1 AU
 - SUN / EARTH ANGLE TO 45°
 - 1 WEEK ORBITAL PERIOD
 - MANEUVERS:
 - STATION KEEPING 1/MONTH
 - ORBIT PLANE CHANGE 1/4 MONTHS
 - MAP WITH SEVERAL REMOTE SENSING
 - PICK A SITE FROM WHICH TO GRAB A SAMPLE
 - GET THE SAMPLE AND ANALYZE IT ON BOARD
- RETURN 100 MBITS/DAY FROM 2AU
- ORBIT DETERMINATION
 - OPTICAL NAVIGATION REQUIRED
 - AUTOMATIC TARGET ACQUISITION REQUIRED
- LIGHT TIME =



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AN OPERATIONALLY SIMPLE MISSION

MISSION PHILOSOPHIES, STRATEGIES & TACTICS

- **LIFE CYCLE COSTS WILL BE MINIMIZED**
- **INITIAL CUT AT MINIMIZING LIFE CYCLE COSTS IS TO USE EXISTING GROUND SYSTEM CAPABILITIES**
- **AFTER FIRST DESIGN OF FLIGHT AND GROUND SEGMENTS, COST DRIVERS WILL BE IDENTIFIED AND EXPLAINED TO SCIENCE WORKING GROUP**
- **SCIENCE WORKING GROUP AND PROJECT WILL ATTEMPT TO LOWER COST DRIVERS AND LIFE CYCLE COST ESTIMATE**



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AN OPERATIONALLY COMPLEX MISSION

MISSION PHILOSOPHIES, STRATEGIES & TACTICS

- **LIFE CYCLE COSTS WILL BE MINIMIZED**
- **INITIAL CUT AT MINIMIZING LIFE CYCLE COSTS IS TO USE EXISTING EXISTING GROUND SYSTEM CAPABILITIES**
- **AFTER FIRST DESIGN OF FLIGHT AND GROUND SEGMENTS, COST DRIVERS WILL BE IDENTIFIED AND EXPLAINED TO SCIENCE WORKING GROUP**
- **SCIENCE WORKING GROUP AND PROJECT WILL ATTEMPT TO LOWER COST DRIVERS AND LIFE CYCLE COST ESTIMATE**



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AN OPERATIONALLY SIMPLE MISSION

PROGRAMMATIC

CONCURRENT ENGINEERING PRACTICES WILL BE USED

COLLOCATION OF PARTICIPANTS DURING DESIGN PHASE



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AN OPERATIONALLY COMPLEX MISSION

PROGRAMMATIC

CONCURRENT ENGINEERING PRACTICES WILL BE USED

COLLOCATION OF PARTICIPANTS DURING DESIGN PHASE



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AN OPERATIONALLY SIMPLE MISSION

INSTRUMENT CHARACTERISTICS

- INSTRUMENT POINTING - NOT REQUIRED
- NUMBER OF INSTRUMENTS = 3
 - FIELDS AND PARTICLES
- INSTRUMENT CONTROL
 - MODE CHANGES ARE AUTONOMOUS
 - NO GROUND COMMANDING OR SEQUENCE REQUIRED FOR DATA GATHERING
 - NO CALIBRATION SEQUENCES OR MANEUVERS REQUIRED
 - INSTRUMENT SOFTWARE UPDATEABLE BUT NOT REQUIRED
- INSTRUMENT OUTPUT
 - PACKET OUTPUT TO SPACECRAFT
 - INSTRUMENT DATA OUTPUT CONTINUOUS AT 1000 BPS



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AN OPERATIONALLY COMPLEX MISSION

INSTRUMENT CHARACTERISTICS

- INSTRUMENT POINTING
 - BODY FIXED INSTRUMENTS
 - COMMON FIELD OF VIEW
 - SPACECRAFT POINTING
 - CONTROL REQUIRED = 0.32°
 - STABILITY = 10^{-3}° over 10 seconds
- NUMBER OF INSTRUMENTS = 3 REMOTE SENSING
- INSTRUMENT CONTROL
 - TYPICAL IMAGING SEQUENCES
 - BUTTON UP WHEN DUST HAZARD TOO STRONG
 - INSTRUMENT SOFTWARE UPDATEABLE
 - MODE CHANGES VIA STORED SEQUENCE
- INSTRUMENT OUTPUT
 - INSTRUMENT OUTPUT BURST MODE
 - INSTRUMENTS OUTPUT PACKETS



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AN OPERATIONALLY COMPLEX MISSION

SPACECRAFT CHARACTERISTICS

- ATTITUDE CONTROL
 - 3 AXIS STABILIZED
 - SUN AND START SENSORS
 - POINTING CONTROL 0.32 °
 - STABILITY - 10-3° over 10 seconds
 - REACTION WHEEL FOR POINTING
 - CONTROL
- POWER
 - POWER MARGIN ZERO AT START OF ORBITAL PHASE
 - SOLAR PANELS & BATTERIES REQUIRE CAREFUL MANAGEMENT TO BALANCE POWER AND THERMAL CONSTRAINTS
- R/F
 - HIGH-GAIN ANTENNA
 - X-BAND
- DATA SYSTEM
 - 8 SELECTABLE DATA RATES
 - ON BOARD SOLID STATE RECORDER 2 GBIT CAPACITY
- PROPULSION
 - 2 PROPULSION SYSTEMS
 - DEEP SPACE BURNS
 - ORBIT KEEPING



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AN OPERATIONALLY SIMPLE MISSION

SPACECRAFT CHARACTERISTICS

- ATTITUDE CONTROL
 - SPIN STABILIZED
 - SPIN AXIS 4° OFF SUNLINE IN T DIRECTION
 - SPIN AXIS ADJUSTED AUTONOMOUSLY ONCE PER DAY
 - ACCURACY $\pm 1^\circ$ (CONTROL & KNOWLEDGE)
- POWER
 - FIXED SOLAR ARRAYS
 - POWER MARGIN $>+25\%$ WITH ALL INSTRUMENTS ON
- R/F
 - S-BAND DOWNLINK
 - SLOTTED WAVEGUIDE ARRAY
- DATA SYSTEM
 - DATA COLLECTION CONTINUOUS
 - 1100 (1000 SCIENCE + 100 health & safety)
 - ALL DATA PACKETIZED
 - SOLID STATE RECORDER (2 GBITS)
 - 30 KBPS DUMP RATE
 - 10 BPS FAULT RECOVERY RATE
- PROPULSION
 - 10 NEWTON THRUSTERS



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EEIS CHARACTERISTICS

- **UPLINK**
 - **SATELLITE**
 - STORE AND DUMP PROCESS REQUIRED FOR SCIENCE DATA
 - ON-BOARD OP NAV REQUIRED DUE TO RENDEZVOUS REQUIREMENTS
 - LIGHT TIME > MANEUVER DURATION
 - ON-BOARD MANEUVER DETERMINATION COUPLED WITH PROPULSION CONTROL
 - **GROUND SYSTEM**
 - SEQUENCES DETERMINED FROM DATA
 - CONTENTION BETWEEN INSTRUMENTS FOR DATA GATHERING
 - SCIENCE USER INPUT REQUIRED FOR SEQUENCE GENERATION
- **DOWNLINK**
 - **SATELLITE**
 - SPACECRAFT AND INSTRUMENTS CONFORM TO CCSDS STANDARDS
 - **GROUND SYSTEM**
 - CONSUMABLES TO MANAGE
 - SOME SUBSYSTEMS HAVE ZERO TO NEGATIVE MARGIN
 - SPACECRAFT ANALYSIS AT SUBSYSTEM LEVEL DUE TO MARGIN DEFICIT
 - MISSION CONTROL - HEALTH AND SAFETY BASED ON PREDICTS

**EEIS CHARACTERISTICS**

- **UPLINK**
 - **SATELLITE**
 - SINGLE ON-BOARD COMPUTER FOR DATA COLLECTION, PROCESSING AND ATTITUDE CONTROL - PROCESSOR LANGUAGE = 'C'
 - INSTRUMENTS HAVE THEIR OWN MICRO PROCESSORS. LANGUAGE ALSO C
 - INSTRUMENTS AND SPACECRAFT DATA SYSTEM CONFORM TO CCSDS STANDARDS
 - SOLID STATE RECORDER ALLOWS DATA STREAM METERING, DUMP AND R/T
 - ALL SUBSYSTEMS HAVE MARGINS
 - **GROUND SYSTEM**
 - ON-BOARD ATTITUDE UPDATES REQUIRE EPHEM UPDATES ONCE PER MONTH
 - NO CONFLICT RESOLUTION REQUIRED FOR SEQ GENERATION
 - NO SEQUENCES REQUIRED FOR NORMAL OPERATIONS
 - NO RESOURCE MANAGEMENT OR PREDICTION REQUIRED
- **DOWNLINK**
 - **SATELLITE**
 - SPACECRAFT AND INSTRUMENTS CONFORM TO CCSDS STANDARDS
 - **GROUND SYSTEM**
 - EDR'S WILL BE TIMED ORDERED SERIES OF PACKETS
 - NO SPECIAL PROCESSING OF SCIENCE DATA
 - MISSION CONTROL - HEALTH AND SAFETY LIMITS ONLY, NO PREDICTIONS REQUIRED
 - SPACECRAFT ANALYSIS AT SYSTEM LEVEL ONLY
 - NO CONSUMABLES TO MANAGE





AN OPERATIONALLY COMPLEX MISSION

GROUND SYSTEM CHARACTERISTICS

- **COMPATIBILITY**
 - SPACECRAFT DATA SYSTEM IS COMPATIBLE WITH AMMOS TELEMETRY SYSTEM
 - R/F COMPATIBLE WITH DSN
- **NAVIGATION**
 - OPTICAL NAVIGATION REQUIRED
- **SEQUENCING**
 - INSTRUMENT SEQUENCING BASED ON RETURNED DATA REQUIRED
 - INSTRUMENT POINTING GENERATION REQUIRED
 - DATA COLLECTION AUTOMATIC
 - SEQUENCES REQUIRED FOR MANEUVERS
 - PRE-PLANNED SEQUENCES REQUIRED FOR INSTRUMENT TURN-ON AND CALIBRATION
 - THESE SEQUENCES WILL BE THE SAME AS THOSE USED DURING SYSTEM TEST



AN OPERATIONALLY SIMPLE MISSION

GROUND SYSTEM CHARACTERISTICS

- **COMPATIBILITY**
 - SPACECRAFT DATA SYSTEM IS COMPATIBLE WITH AMMOS TELEMETRY SYSTEM
 - R/F COMPATIBLE WITH DSN
- **NAVIGATION**
 - NO SPECIAL NAVIGATION REQUIREMENTS
- **SEQUENCING**
 - NO INSTRUMENT SEQUENCING REQUIRED
 - DATA COLLECTION AUTOMATIC
 - SEQUENCES REQUIRED FOR MANEUVERS
 - PRE-PLANNED SEQUENCES REQUIRED FOR INSTRUMENT TURN-ON AND CALIBRATE SAME AS THOSE USED DURING SYSTEM TEST





AN OPERATIONALLY SIMPLE MISSION

USER DATA PRODUCT DEFINITION

- QUICK-LOOK DATA FOR HEALTH CHECKS, INCLUDING SPIN-AXIS POINTING AND INSTRUMENT OPERATION
- EXPERIMENT DATA RECORDS FOR NONREAL-TIME ANALYSIS



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AN OPERATIONALLY COMPLEX MISSION

USER DATA PRODUCT DEFINITION

- IMAGING DATA IN FRAME FORMAT
- NO CALIBRATION REQUIRED
- SPICE KERNELS



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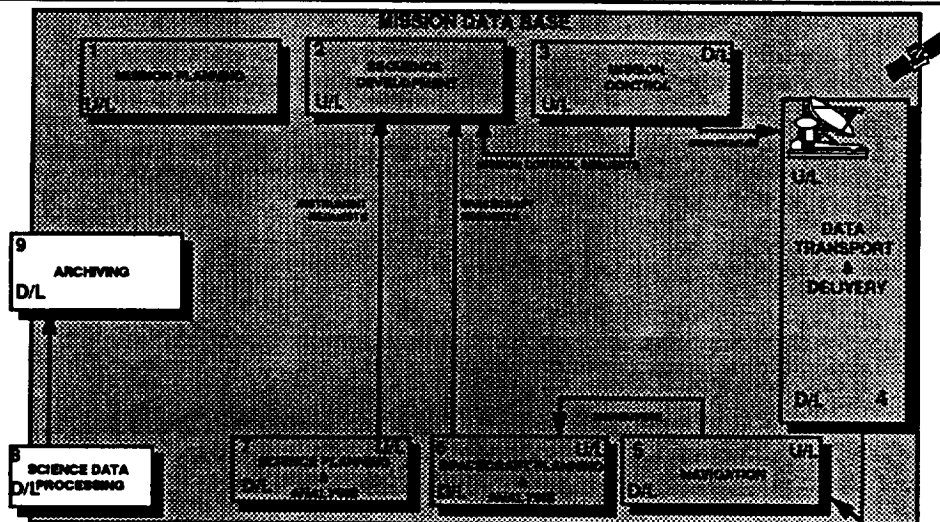
SCIENCE DATA PROCESSING and ANALYSIS

William B. Green

Functional Area Manager: Operational Science Analysis
Multimission Operations Systems Office

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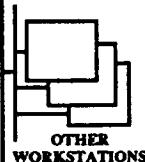
SCIENCE DATA PROCESSING AND ANALYSIS



- **FUTURE LOW COST MISSION OPERATIONS WILL INCREASINGLY INVOLVE SCIENCE TEAMS SUPPORTING FLIGHT OPERATIONS FROM THEIR HOME INSTITUTIONS**
- **TECHNOLOGY EVOLUTION SUPPORTS DISTRIBUTED OPERATIONS SUPPORT SCENARIOS**
 - **HIGH-PERFORMANCE WORKSTATIONS**
 - **HIGH-SPEED NETWORKS**
 - **PLATFORM-INDEPENDENT SOFTWARE**

**SCIENCE OPERATIONS SUPPORT WORKSTATION**

**MISSION PLANNING & SEQUENCE
DEVELOPMENT TOOLS
SPACECRAFT PERFORMANCE & ANALYSIS
TOOLS
POSITION LOCATION PLANNING &
ANALYSIS TOOLS
SCIENCE DATA PROCESSING TOOLS
LOCAL DATABASE & DATA MANAGEMENT
TOOLS**

**OTHER
WORKSTATIONS****Low Cost Mission Operations Workshop****WBG - 3****THE "SOPC"**

- **"SCIENCE OPERATIONS PLANNING COMPUTER" (SOPC) CONCEPT WAS FIRST UTILIZED TO SUPPORT MARS OBSERVER AND IS PLANNED FOR CASSINI**
 - **CAPABILITIES CAN BE READILY ADAPTED TO DISCOVERY MISSIONS**
- **CONCEPT INVOLVES PACKAGING MISSION SUPPORT TOOLS IN A UNIX-BASED WORKSTATION ENVIRONMENT DISTRIBUTED TO SCIENCE TEAMS**
- **SOPC CAPABILITIES CAN BE A COMBINATION OF JPL- AND P.I.- DEVELOPED OPERATIONS SUPPORT TOOLS**
- **JPL LONG-TERM MAINTENANCE OF JPL-DEVELOPED SOFTWARE TOOLS**
- **MANY OF THE TOOLS SHOWN TODAY CAN BE PROVIDED WITHIN A "SOPC"**

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SCIENCE DATA PROCESSING AND ANALYSIS

OUTLINE

- ➔ • DATA FLOW AND PRODUCTS
 - ONBOARD SCIENCE INSTRUMENT DATA PROCESSING
 - SCIENCE INSTRUMENT DATA RECORD ASSEMBLY
 - SCIENCE DATA MANAGEMENT
 - SCIENCE ANALYSIS PROCESSING SUPPORT
 - SCIENCE DATA PRODUCT GENERATION

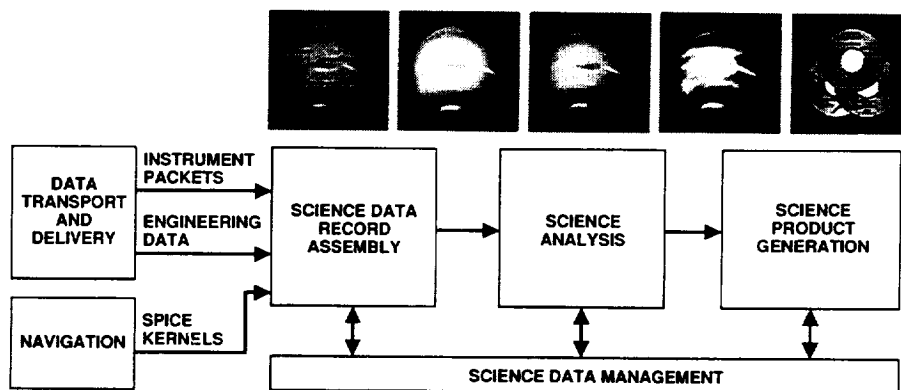


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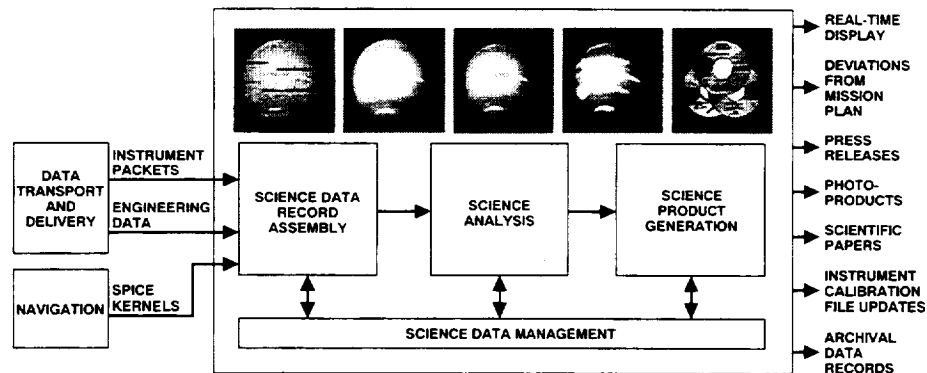


DATA FLOW



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- **TECHNOLOGY SUPPORTS INCREASED PROCESSING OF SCIENCE DATA ON THE SPACECRAFT. EXAMPLES:**
 - DATA COMPRESSION
 - LOSSLESS AND LOSSY CAN BE ADAPTIVE
 - INSTRUMENT SIGNATURE REMOVAL
 - INFORMATION EXTRACTION
 - ENCODING TO PREVENT DATA LOSS IN THE TELEMETRY LINK
- **SOME ONBOARD PROCESSING MUST BE REVERSED ON THE GROUND. EXAMPLES:**
 - DECODING
 - DECOMPRESSION

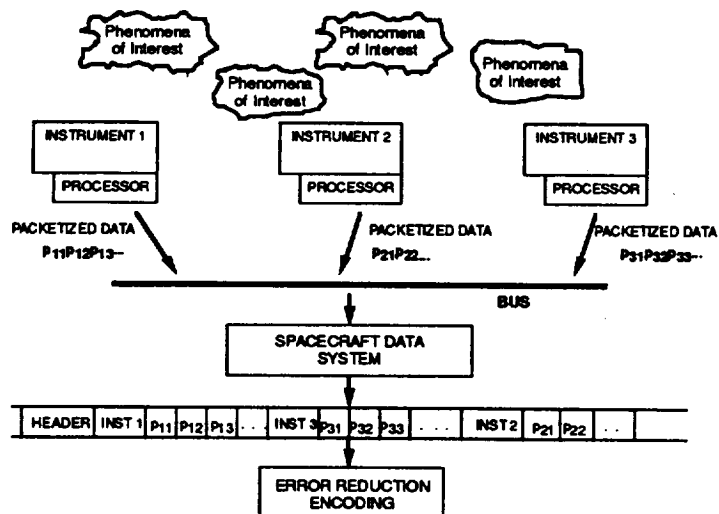


OUTLINE

- DATA FLOW AND PRODUCTS
- ➔ • ONBOARD SCIENCE INSTRUMENT DATA PROCESSING
- SCIENCE INSTRUMENT DATA RECORD ASSEMBLY
- SCIENCE DATA MANAGEMENT
- SCIENCE ANALYSIS PROCESSING SUPPORT
- SCIENCE DATA PRODUCT GENERATION



TYPICAL FLOW OF SCIENCE INSTRUMENT DATA THROUGH SPACECRAFT DATA SYSTEM



- NASA-FUNDED UNIX-BASED SOFTWARE SYSTEM USED TO DESIGN SCIENCE INSTRUMENT PACKETS
- ASSISTS IN EVALUATING ROBUSTNESS OF PACKET FORMAT DESIGN IN PRESENCE OF NOISE OR PACKET LOSS

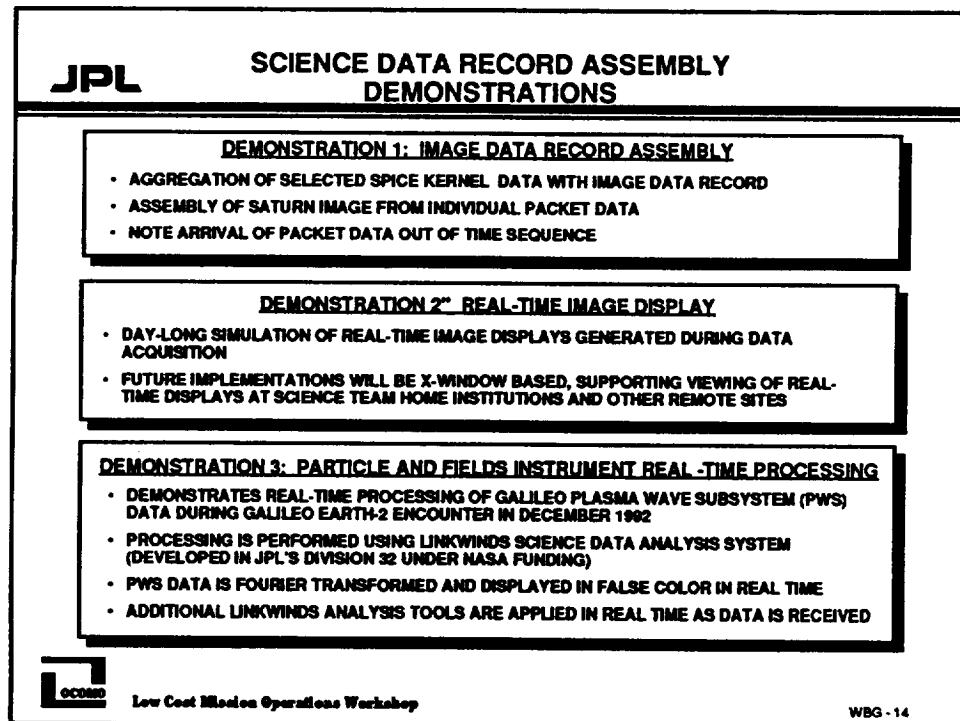
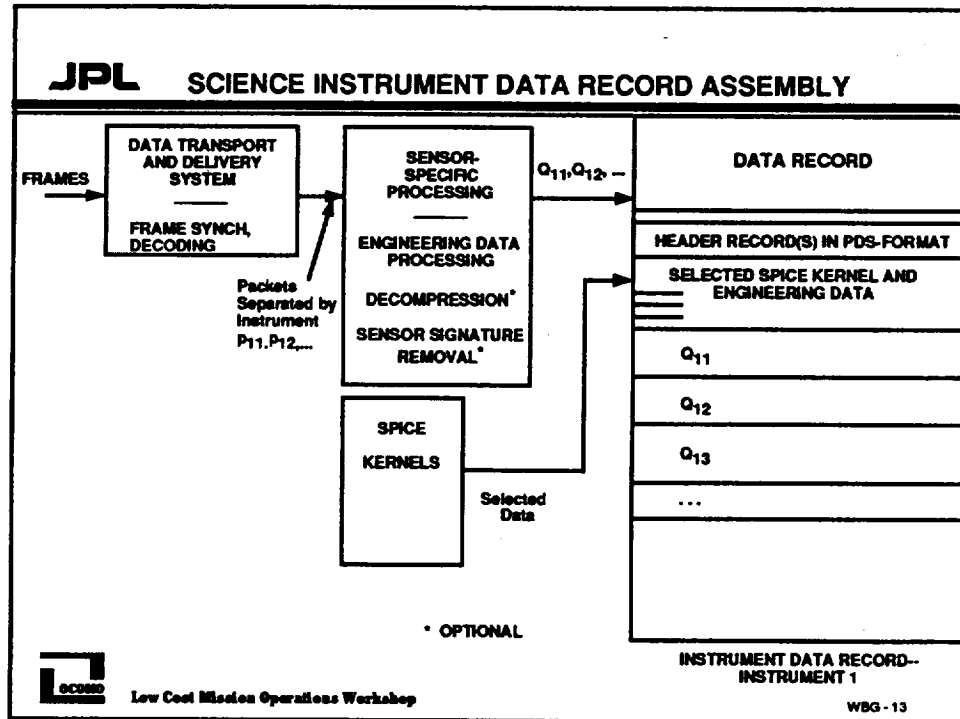
DEMONSTRATION

- COMPRESSED IMAGES (JPEG COMPRESSION) DOWNLINKED WITH NO ERROR CORRECTION CODE, BIT ERROR RATE (BER) 10^{-4}
- SAME IMAGE COMPRESSION AND BER WITH REED-SOLOMON CODING
- COMPARISON OF COMPRESSED IMAGE (COMPRESSION RATIO APPROXIMATELY 20:1) WITH UNCOMPRESSED IMAGE TO ILLUSTRATE DATA LOSS IN COMPRESSION

**OUTLINE**

- DATA FLOW AND PRODUCTS
- ONBOARD SCIENCE INSTRUMENT DATA PROCESSING
- ➔ • SCIENCE INSTRUMENT DATA RECORD ASSEMBLY
- SCIENCE DATA MANAGEMENT
- SCIENCE ANALYSIS PROCESSING SUPPORT
- SCIENCE DATA PRODUCT GENERATION





JPL COST DRIVERS-- SCIENCE INSTRUMENT DATA RECORD ASSEMBLY

- **PERCENTAGE OF ACQUIRED SOURCE DATA IN THE EXPERIMENT DATA RECORD (EDR)**
 - REQUIREMENTS FOR 100% OF DATA MAY DRIVE OPERATIONS COSTS BY REQUIRING MULTIPLE PLAYBACKS AND DATA-MERGE OPERATIONS
 - IS "REAL-TIME" DATA RECORD ASSEMBLY AND DISTRIBUTION REQUIRED, OR CAN DATA BE PROCESSED IN BATCHES AT TIMES NOT DRIVEN BY DATA ACQUISITION TIMES?
- **TIMELINESS OF SPICE KERNEL DATA**
 - PRECISION OF NAVIGATION INFORMATION INCREASES WITH TIME
 - INSTRUMENT DATA ANALYSIS MAY IMPROVE NAVIGATION DATA PRECISION
 - WAITING FOR THE BEST POSSIBLE SPICE KERNEL DATA BEFORE PRODUCING EXPERIMENT DATA RECORDS CAN CAUSE MULTIPLE PRODUCTION RUNS
- **VOLUME OF DATA**
 - DISTRIBUTION QUANTITIES OF FINAL PRODUCTS SUPPORTED BY PROJECT FUNDING
 - DISTRIBUTION MEDIA USED FOR FINAL PRODUCTS
 - DIGITAL MEDIA--TAPE, CD-ROM
 - FILM MEDIA--QUANTITY AND NUMBER OF COPIES DISTRIBUTED



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JPL IMPLEMENTATION OPTIONS-- SCIENCE INSTRUMENT DATA RECORD PRODUCTION

- **ADAPT JPL MULTIMISSION CAPABILITIES, PRODUCE FINAL EDR'S AT JPL FACILITIES**
 - JPL TRANSMITS ASSEMBLED DATA RECORDS (REAL TIME AND FINAL EDR) TO SCIENCE TEAM SITE(S) ELECTRONICALLY
 - JPL TRANSFERS SELECTED DATA RECORDS ON REQUEST TO SCIENCE TEAM SITES (ELECTRONICALLY OR VIA CD-ROM SHIPMENT)
- **SCIENCE TEAM IMPLEMENTS AND OPERATES FACILITIES TO PRODUCE FINAL EDR'S**
 - JPL TRANSMITS PACKET-LEVEL DATA TO SCIENCE TEAM FACILITY
 - SCIENCE TEAM IS RESPONSIBLE FOR OPERATIONAL SUPPORT OF DATA RECORD PRODUCTION
- **EDR'S ARE PRODUCED AT SCIENCE TEAM FACILITIES USING MULTIMISSION SOFTWARE AND PROCEDURES ADAPTED BY JPL**
 - JPL DELIVERS TESTED SOFTWARE AND PROCEDURES TO P.I. SITES
 - SCIENCE TEAM IS RESPONSIBLE FOR OPERATIONAL SUPPORT TO DATA RECORD PRODUCTION



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SCIENCE DATA PROCESSING AND ANALYSIS

OUTLINE

- DATA FLOW AND PRODUCTS
- ONBOARD SCIENCE INSTRUMENT DATA PROCESSING
- SCIENCE INSTRUMENT DATA RECORD ASSEMBLY
- ➔ • SCIENCE DATA MANAGEMENT
- SCIENCE ANALYSIS PROCESSING SUPPORT
- SCIENCE DATA PRODUCT GENERATION



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SCIENCE DATA MANAGEMENT REQUIREMENTS AFTER RECEIPT OF DATA

- NEED TO BE ABLE TO LOCATE ALL VERSIONS OF ALL DATA RECEIVED TO DATE, BASED ON VARIOUS SEARCH CRITERIA
- ABILITY TO DISCRIMINATE BETWEEN DIFFERENT VERSIONS OF SAME INSTRUMENT DATA
 - DIFFERENT SPACECRAFT DOWNLINKS (WITH DIFFERENT PROCESSING OPTIONS?)
 - DIFFERENT DEEP SPACE NETWORK (DSN) STATION PLAYBACKS
 - DIFFERENT LEVELS OF INSTRUMENT DATA PROCESSING
 - DIFFERENT DATA QUALITY LEVELS ON DIFFERENT VERSIONS OF DOWNLINK DATA
- NEED TO CORRELATE ANCILLARY DATA WITH INSTRUMENT DATA
 - GEOGRAPHIC REFERENCE FRAMEWORK FOR OBSERVATIONS
 - CORRELATION OF INSTRUMENT ENGINEERING DATA WITH OBSERVATIONAL DATA
- ABILITY TO CORRELATE OBSERVATIONS BETWEEN MULTIPLE INSTRUMENTS



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SCIENCE DATA MANAGEMENT SYSTEM CAPABILITIES REQUIRED DURING OPERATIONS

- INTERACTIVE USER DATABASE QUERY AND DATA RETRIEVAL, BASED ON MULTIPLE SEARCH CRITERIA
- GENERATION AND AUTOMATIC E-MAIL DISTRIBUTION OF STANDARD REPORTS
 - SUMMARY OF DAILY DATA RECEIPT BY INSTRUMENT
 - PROJECT MANAGEMENT REPORTS THAT SUMMARIZE PROCESSING STATUS
- AUTOMATIC INITIATION OF PROCESSING SEQUENCES, BASED ON RECEIPT OF ANTICIPATED DATA



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SCIENCE DATA QUERY/ RETRIEVAL DEMONSTRATIONS

- DEMONSTRATIONS UTILIZE "DBVIEW," A MULTIMISSION USER INTERFACE TO SCIENCE DATABASES DEVELOPED AT JPL
- SYSTEM UTILIZES THE SYBASE DATABASE, A COMMERCIALLY AVAILABLE DATABASE MANAGEMENT SYSTEM (DBMS)
- CLIENT SOFTWARE SUPPORTS REMOTE SCIENCE USERS, WITHOUT NEED FOR SYBASE SITE LICENSES AT REMOTE SITES

DEMONSTRATION 1: DAILY REPORT

A TYPICAL DAILY REPORT, TRANSMITTED TO A SCIENCE TEAM VIA ELECTRONIC MAIL THAT LISTS MOST RECENTLY ACQUIRED DATA

DEMONSTRATION 2: INTERACTIVE QUERY

INITIATION OF A QUERY BY A SCIENCE TEAM MEMBER AT A REMOTE SITE, SEARCHING FOR ALL DATA THAT MEETS SELECTED SEARCH CRITERIA



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SCIENCE DATA MANAGEMENT SYSTEM DURING MISSION OPERATIONS:

IMPLEMENTATION OPTIONS

- SERVER LOCATED AT JPL, DATABASE LOCATED AT JPL, CLIENT SOFTWARE OPERATES IN USER WORKSTATIONS
 - UTILIZE JPL MULTIMISSION CAPABILITIES AND SHARED OPERATIONS STAFF
 - ALL INSTRUMENT DATA, ANCILLARY DATA, AND ASSOCIATED CATALOGS ARE MAINTAINED AT JPL USING COMMERCIAL DBMS TECHNOLOGY FOR THE DURATION OF THE MISSION
 - SECURE LINKS OR PUBLIC DOMAIN NETWORKS SUPPORT REMOTE SCIENCE QUERY/RETRIEVAL VIA JPL-PROVIDED CLIENT SOFTWARE OR PUBLIC-DOMAIN TOOLS
 - CENTRALIZED SYSTEM ACCEPTS AND CATALOGS DATA PRODUCTS GENERATED AT REMOTE SCIENCE SITES

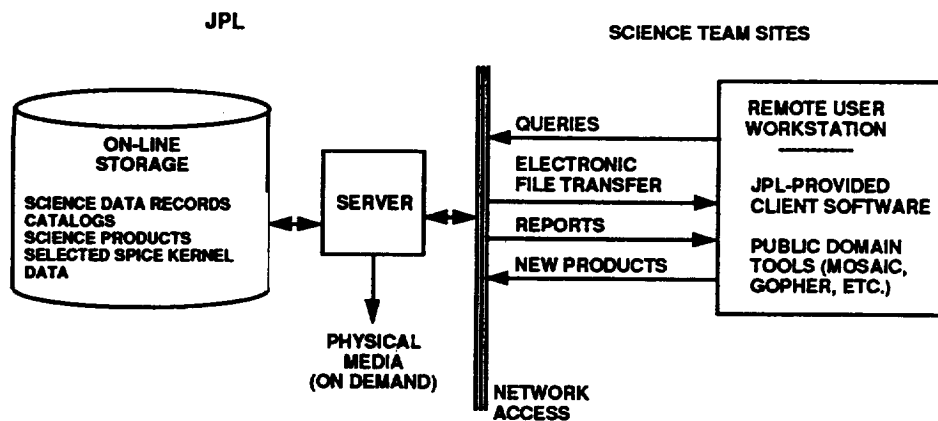


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SCIENCE DATA MANAGEMENT SERVER AT JPL



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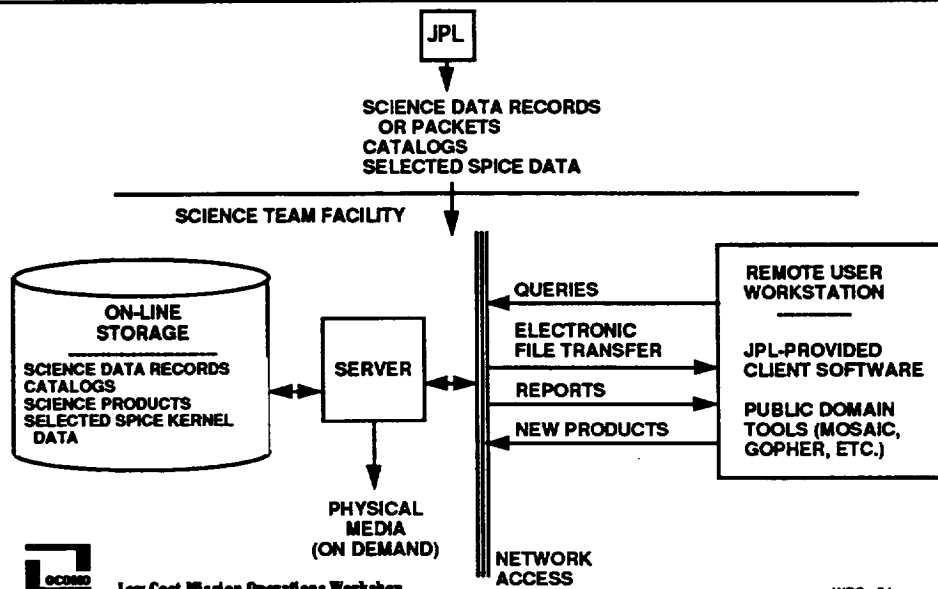
SCIENCE DATA MANAGEMENT SYSTEM DURING MISSION OPERATIONS:

IMPLEMENTATION OPTIONS (Continued)

- **DISTRIBUTED DATABASE CONCEPTS**
 - JPL TRANSFERS PACKETS OR DATA RECORDS TO TEAM SITE (DESCRIBED PREVIOUSLY)
 - SCIENCE TEAM ASSUMES RESPONSIBILITY FOR CATALOG GENERATION AND MAINTENANCE, AND FOR SUPPORT OF SCIENCE TEAM QUERY/RETRIEVAL
 - POTENTIAL USE OF JPL-DEVELOPED CAPABILITIES IN THESE SCENARIOS



SCIENCE DATA MANAGEMENT SUPPORT AT SCIENCE TEAM SITE(S)





SCIENCE DATA PROCESSING AND ANALYSIS

OUTLINE

- DATA FLOW AND PRODUCTS
- ONBOARD SCIENCE INSTRUMENT DATA PROCESSING
- SCIENCE INSTRUMENT DATA RECORD ASSEMBLY
- SCIENCE DATA MANAGEMENT
- ➔ • SCIENCE ANALYSIS PROCESSING SUPPORT
- SCIENCE DATA PRODUCT GENERATION



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SCIENCE ANALYSIS PROCESSING SUPPORT:

IMPLEMENTATION OPTIONS

- SOFTWARE FOR PRODUCTION OF HIGHER ORDER SCIENCE ANALYSIS PRODUCTS AVAILABLE FROM MULTIPLE SOURCES:
 - JPL AND OTHER GOVERNMENT AGENCIES
 - VICAR, LINKWINDS, PICS (USGS)
 - COMMERCIAL SOURCES
 - IDL, PVWAVE, AVS
 - PUBLIC DOMAIN PACKAGES
 - KHOROS
 - P.I. AND SCIENCE TEAM FACILITIES
- EVOLVING TECHNOLOGY SUPPORTS INCREASING ROLE FOR SCIENCE TEAMS IN PRODUCTION OF HIGHER LEVEL PRODUCTS BEYOND THE EDR
- INDIVIDUAL SCIENCE TEAMS WILL MAKE DECISIONS ON SUPPORTING SCIENCE ANALYSIS
- PROCESSING BASED ON THEIR OWN CAPABILITIES, AVAILABLE FACILITIES, AND COST
- JPL CAPABILITIES ARE AVAILABLE TO SUPPORT SCIENCE ANALYSIS AT SCIENCE FACILITIES OF NASA-FUNDED SCIENCE TEAM MEMBERS



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**DEMONSTRATION: CAPABILITIES NOT NORMALLY FOUND IN
COMMERCIALY AVAILABLE OR PUBLIC-DOMAIN SOFTWARE**

- CARTOGRAPHIC PROJECTIONS FOR BODIES OTHER THAN THE EARTH
- INTERFACE WITH ANCILLARY DATA FILES (e.g., SPICE KERNEL, SPACECRAFT ENGINEERING DATA SOURCES)
- ABILITY TO HANDLE DATA SETS OF LARGE DIMENSIONS (e.g., LARGE DIGITAL IMAGE MOSAICS, MULTISPECTRAL INSTRUMENTS)
- RADIOMETRIC RECONSTRUCTION OF COLOR IMAGERY FROM MULTIPLE IMAGES ACQUIRED THROUGH SPECTRAL FILTERS
- IMAGE REGISTRATION TO LESS THAN ONE PIXEL ACCURACY

**OUTLINE**

- DATA FLOW AND PRODUCTS
- ONBOARD SCIENCE INSTRUMENT DATA PROCESSING
- SCIENCE INSTRUMENT DATA RECORD ASSEMBLY
- SCIENCE DATA MANAGEMENT
- SCIENCE ANALYSIS PROCESSING SUPPORT
- ➔ • SCIENCE DATA PRODUCT GENERATION





SCIENCE DATA PRODUCT GENERATION

- THE PRINCIPAL INVESTIGATOR'S DELIVERABLE TO NASA IS AN ARCHIVAL-QUALITY DATA RECORD IN PLANETARY DATA SYSTEM (PDS) COMPATIBLE FORMAT
- PDS IS RESPONSIBLE FOR POST-MISSION DATA RETENTION AND DISSEMINATION
- P.I. DETERMINES CONTENT OF PDS DELIVERABLE PRODUCT
 - LEVEL OF PROCESSING OF INSTRUMENT DATA
 - DELIVERY OF INSTRUMENT CALIBRATION DATA
 - ANCILLARY DATA INCORPORATED INTO DATA PRODUCT
 - SOFTWARE
 - DOCUMENTATION
- CURRENT MEDIUM OF CHOICE FOR PDS PRODUCTS IS CD-ROM

DEMONSTRATION: PLANETARY ANALYSIS TOOL (PLATO)

- NASA-FUNDED SOFTWARE THAT SUPPORTS QUERY AND RETRIEVAL OF IMAGE DATA FROM PDS CD-ROMS
- DEMONSTRATION ILLUSTRATES RETRIEVAL OF IMAGE DATA BASED ON SPECIFIC SEARCH CRITERIA
- PLATO ALSO SUPPORTS APPLICATION OF INSTRUMENT CALIBRATION FILES TO IMAGE DATA, INTERFACE WITH SPICE KERNELS, AUTOMATIC MOSAICKING, AND OTHER FEATURES



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THE PLANETARY DATA SYSTEM (PDS)

- ORGANIZATION:
 - PDS DISCIPLINE NODES DEFINE SCIENTIFIC OBJECTIVES AND ESTABLISH PRIORITIES FOR RESTORATION OF OLDER DATA SETS
 - NODES INCLUDE GEOSCIENCES, ATMOSPHERES, PLANETARY PLASMA INTERACTIONS, IMAGING, RINGS, SMALL BODIES, NAVIGATION ANCILLARY INFORMATION FACILITY (NAIF), SPICE KERNEL
 - PDS CENTRAL NODE AT JPL ESTABLISHES STANDARDS AND WORKS WITH ACTIVE MISSIONS TO DEFINE ARCHIVAL PDS-COMPATIBLE DATA SETS
- ROLE:
 - PROVIDE THE BEST PLANETARY DATA TO THE MOST USERS FOREVER
- DATA RESTORATION ROLE:
 - PUBLISH COMPLETE ARCHIVE PRODUCTS FROM PAST PLANETARY MISSIONS FOLLOWING PRODUCT DESIGN, PEER REVIEW OF DATA AND DESCRIPTIVE LABELS, AND VALIDATION OF THE PRODUCTS



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ADAPTATION EXAMPLE--MARS PATHFINDER

- **PAYLOAD**
 - LANDER STEREO COLOR CAMERA, ROVER CAMERAS, AXP
- **APPROACH**
 - JPL MULTIMISSION FACILITIES USED FOR:
 - REAL-TIME PROCESSING, DECOMPRESSION, DATA RECORD FORMATION, PHOTOPRODUCTS, REAL-TIME DISPLAY, DATABASE MAINTENANCE AND CATALOG, PRODUCTION OF PDS-COMPATIBLE EDR'S ON CD-ROM
 - DEDICATED UNIX WORKSTATION USED TO SUPPORT THESE ACTIVITIES
 - LANDER IMAGING SCIENCE TEAM PERFORMS HIGHER LEVEL LANDER IMAGE PROCESSING
 - ROVER NAVIGATION TEAM PERFORMS STEREO IMAGE ANALYSIS AND ROVER NAVIGATION COMPUTATION
 - AXP SCIENCE TEAM PERFORMS PROCESSING BEYOND LEVEL 0
- **TOTAL DEVELOPMENT FOR LESS THAN \$200K IN REAL-YEAR DOLLARS BY ADAPTING JPL MULTIMISSION CAPABILITIES THAT SUPPORT THE FUNCTIONS SHOWN ABOVE**



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"UNSCRIPTED DEMONSTRATIONS" LATER TODAY IN VON KARMAN AUDITORIUM

- **AESOP**
 - ADVANCED END-TO-END SIMULATION OF ONBOARD PROCESSING
- **VICAR**
 - INSTRUMENT DATA PROCESSING SOFTWARE
- **LINKWINDS**
 - SCIENCE ANALYSIS SUPPORT SYSTEM
- **PLATO**
 - PROCESSING AND DISPLAY OF IMAGE DATA FROM PDS DATA SETS
- **DBVIEW**
 - SCIENCE DATA MANAGEMENT SYSTEM CLIENT SOFTWARE
- **STEREO AND ANIMATION**



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SCIENCE DATA PROCESSING AND ANALYSIS

INPUT	FUNCTIONS	OUTPUT
INSTRUMENT PACKET DATA	DECOMPRESSION (IF REQUIRED)	DEVIATIONS FROM BASELINE MISSION PLAN
ANCILLARY DATA (SPICE KERNELS)	AGGREGATION OF PACKET LEVEL DATA INTO INSTRUMENT DATA RECORDS (LEVEL 0)	INSTRUMENT CALIBRATION FILE UPDATES
ENGINEERING DATA	CORRELATION OF INSTRUMENT DATA RECORDS WITH ANCILLARY AND ENGINEERING DATA	QUICK-LOOK AND ARCHIVAL DATA RECORDS
	GENERATION OF INSTRUMENT DATA CATALOGS AND INDICES	SCIENTIFIC PAPERS
	GENERATION OF HIGHER LEVEL SCIENCE DATA RECORDS (LEVEL 1 AND ABOVE)	HARD COPY PRODUCTS
	PREPARATION OF ARCHIVAL DATA RECORDS FOR DELIVERY TO PDS AND NSSDC	PRESS RELEASES
	DATA ANALYSIS	REAL-TIME DATA DISPLAY
	PUBLIC INFORMATION OFFICE PRESS RELEASE PREPARATION	
	INSTRUMENT PERFORMANCE ANALYSIS	



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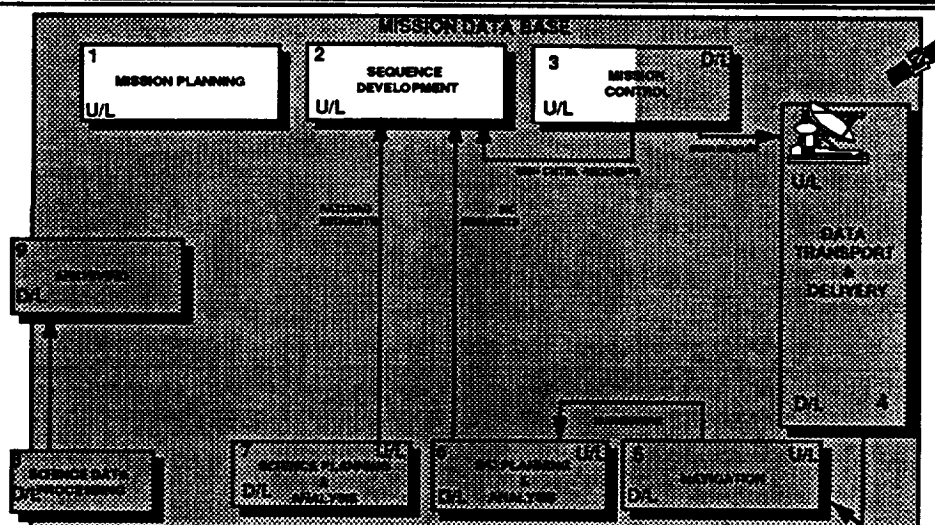
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MISSION DESIGN, PLANNING, and SEQUENCING

Dr. Thomas W. Starbird
Sequence System Engineer
Multimission Operations Systems Office

TS-1





MISSION DESIGN, PLANNING, AND SEQUENCING

OUTLINE

- UPLINK PROCESS
- UPLINK PLANNING PROCESSES
- ADAPTATION SUMMARY
- HOW TO REDUCE COSTS
- PARTNERSHIP OPTIONS



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UPLINK PLANNING AND SEQUENCING

TRANSFORM SCIENTIFIC AND ENGINEERING GOALS INTO
SPACECRAFT EVENTS



PLANNING AND SEQUENCING



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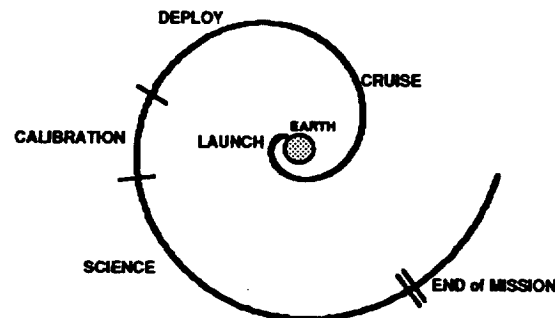
TS - 4



- MISSION DESIGN
- MISSION PLANNING
- SCIENCE OBSERVATION GENERATION
- OBSERVATION INTEGRATION
- POINTING OBSERVATION DESIGN
- SEQUENCE GENERATION AND INTEGRATION
- COMMAND LOAD GENERATION
- SEQUENCE VERIFICATION
- GROUND SEQUENCE GENERATION

PLANNING

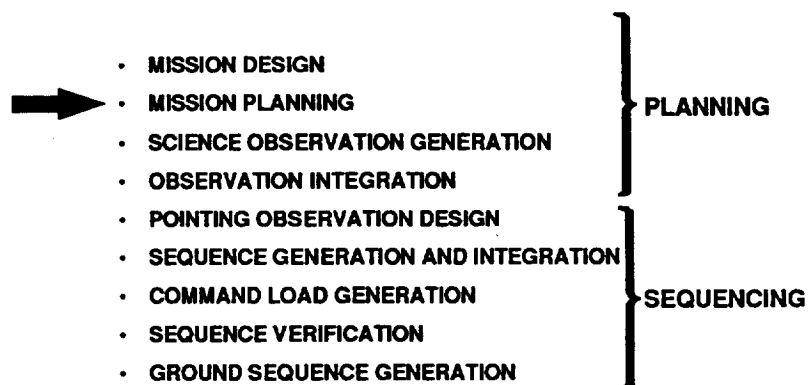
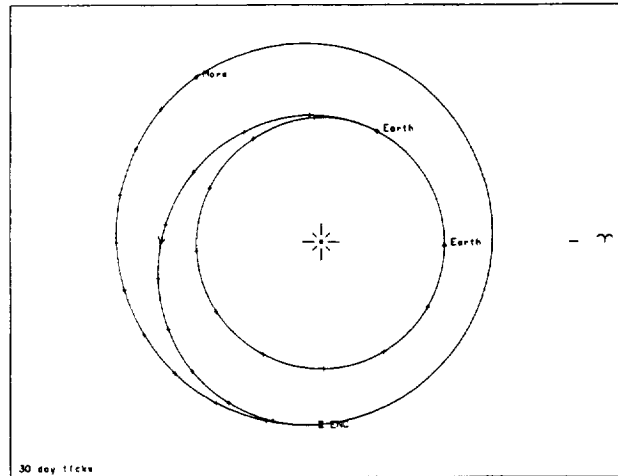
SEQUENCING

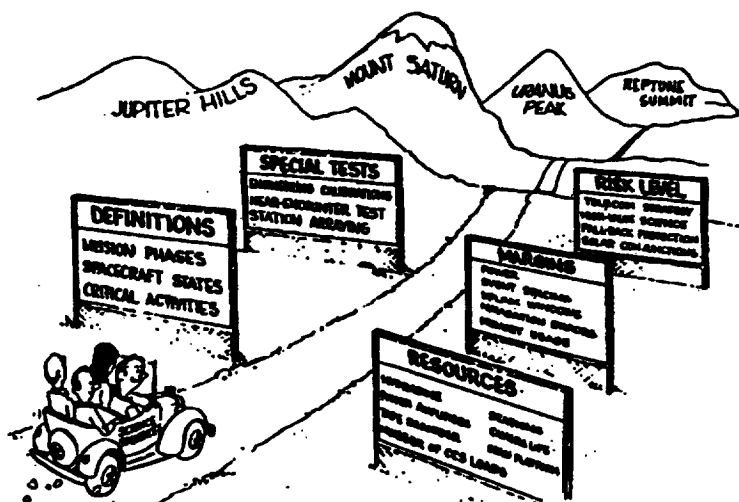
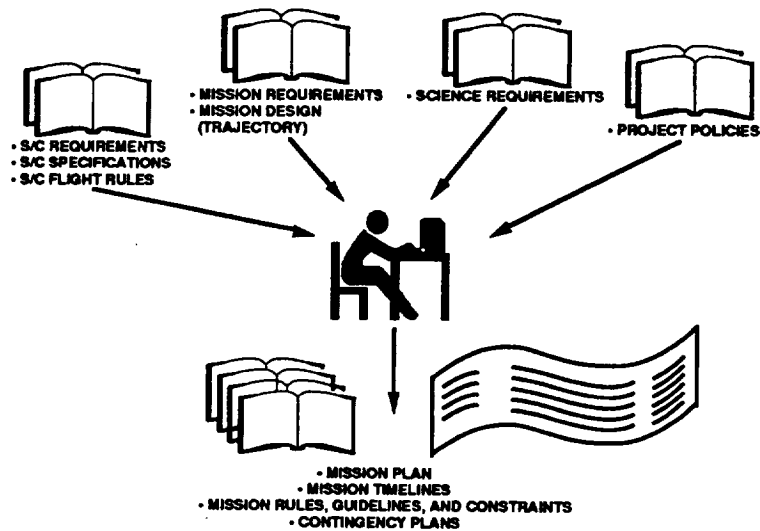


- TRAJECTORY CHOSEN
- OPERATIONS CONCEPT DEVELOPED
- SCIENCE SCENARIOS DEVELOPED
- GROUND TOOLS DEVELOPED



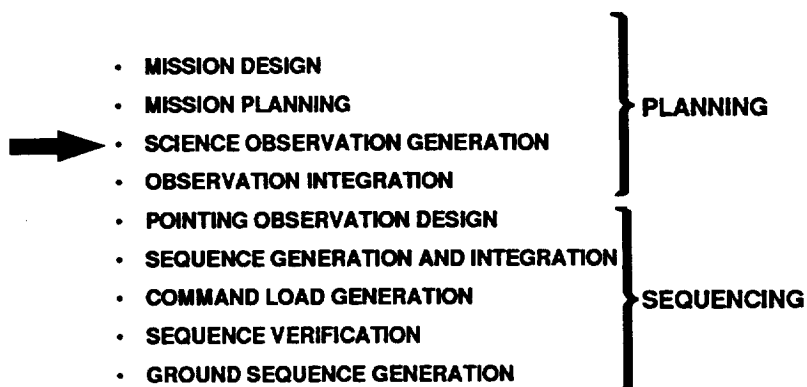
LP Close : Launch 11/24/96 - Arrival 09/21/97





EXAMPLES

- SCHEDULE SPACECRAFT EVENTS THAT REQUIRE REAL-TIME MONITORING DURING PRIME SHIFT
- DO NOT REQUIRE UPLINKS DURING SOLAR CONJUNCTION
- DO NOT OVERWRITE CRITICAL DATA STORED ON RECORDER UNTIL PLAYBACK DATA IS VERIFIED
- RECORD CRITICAL DATA AS WELL AS TRANSMITTING IT IN REAL TIME
- RECORD TELEMETRY 15 MINUTES BEFORE AND AFTER CRITICAL ACTIVITIES
- ALLOCATE RESOURCES TO ACTIVITIES AND MISSION PHASES, TO ENSURE ADEQUATE RESOURCES FOR FUTURE TASKS



- **DETERMINE OBSERVATION OPPORTUNITIES BASED ON**
 - **SCIENCE GOALS**
 - **GEOMETRY, EPHEMERIDES, AND SCIENCE MODELS**
- **SPECIFY OBSERVATION AT HIGH LEVEL**

**DEMONSTRATION OF SEQ_POINTER FOR
PLANETARY ENCOUNTER OF SATURN**

- **VISUALIZING IMAGING FOOTPRINTS ON SATURN**
- **CHANGE TIME OF OBSERVATION**
 - **FOOTPRINTS CHANGE**
- **CHANGE NUMBER OF MOSAIC IMAGES**



● COMPUTES GEOMETRIC QUANTITIES

- EPHEMERIDES (SPACECRAFT and SOLAR BODIES)
 - CONICS
 - SPICE KERNEL (INTEGRATED TRAJECTORY)
- COORDINATE SYSTEMS
- 3-D IMAGE, TARGET BODY, AND FOOTPRINTS
- LIGHTING ANGLES, SLANT RANGE TO TARGET ...

○ APPLIES SPACECRAFT CHARACTERISTICS

- **FIELD OF VIEW**
- **SLEW / TURN RATES, CONSTRAINTS**
- **ONBOARD CAPABILITIES (e.g., MOSAIC)**

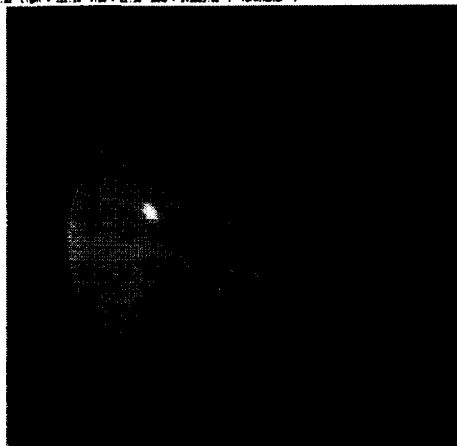
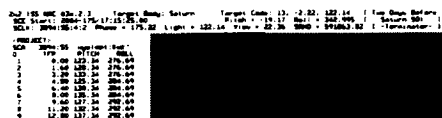
- IS INTERACTIVE WITH USER
- READS / WRITES FILE INTERFACES, WITH SEQ GEN

■ or ● No adaptation required

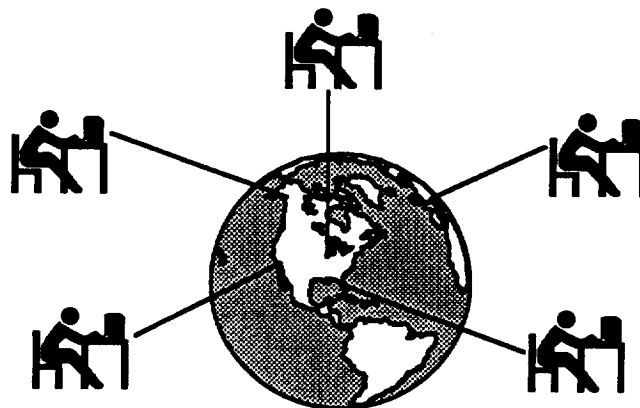
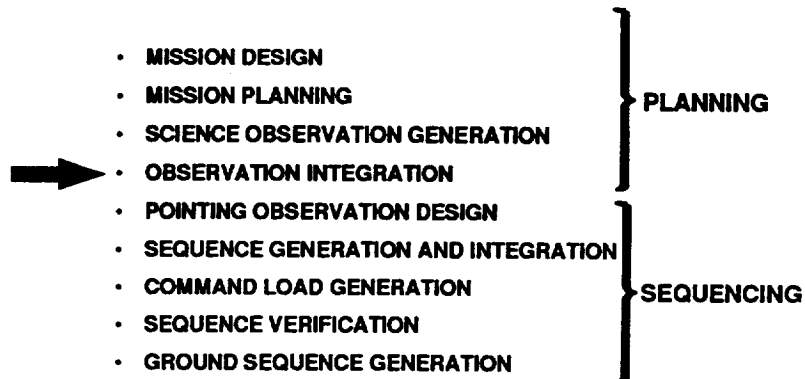
- Requires adaptation to project needs



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- **MERGE SCIENCE OBSERVATIONS, ENGINEERING, AND NAVIGATION ACTIVITIES**
- **MODEL KEY LIMITED OR SHARED RESOURCES (SPACECRAFT AND GROUND)**
 - **INTERACTION OF OBSERVATIONS WITH SPACECRAFT RESOURCES**
 - **INTERACTION OF OBSERVATIONS WITH GROUND (e.g., TRACKING STATIONS)**
 - **INTERACTION OF OBSERVATIONS WITH EACH OTHER**
 - **INTERACTION OF OBSERVATIONS WITH ENGINEERING AND NAVIGATION**
- **RESOLVE CONFLICTS**



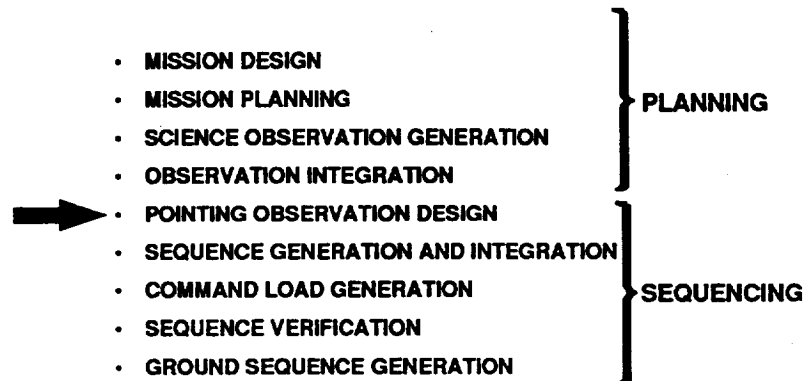
**DEMONSTRATION OF PLAN-IT II FOR
PROTOTYPE OF EARTH OBSERVING SYSTEM (DOS)
DISTRIBUTED SCHEDULING CONCEPT**

- **GENERATE TARGET OBSERVATIONS**
- **GENERATE SLEWS TO CORRECT POINTING CONFLICTS**
- **GENERATE GLOBAL MAPPING OBSERVATIONS TO FILL AVAILABLE TIME**
- **ACCEPT REMOTE, EXTRA OBSERVATION REQUEST AND RESOLVE CONFLICT**

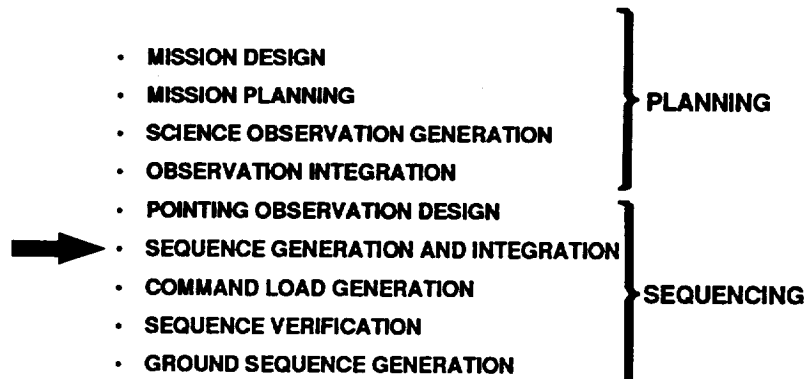


- THE STATE-OF-THE-ART "SPREAD SHEET" APPROACH TO TIMELINE INTEGRATION AND CONFLICT DETECTION / RESOLUTION
 - PANOPLY OF RESOURCE TYPES, CONSTRAINT TYPES
 - ADAPTER CHOOSES
 - PANOPLY OF ACTIONS TO CHANGE PLAN
 - APPLIED BY USER OR ALGORITHM
 - FULL CONNECTIVITY BETWEEN ACTIVITIES AND RESOURCES
 - REPORTS ALL CONTRIBUTORS TO CONFLICTS
 - DISCREET EVENTS AND INTERVAL ACTIVITIES
 - MULTIPLE LEVELS OF ABSTRACTION
 - ADAPTER CAN AUTOMATE PLANNING STRATEGIES
 - EXAMPLE: PLACE OBSERVATION TO MINIMIZE CONFLICTS
 - HANDLES EVENT-DRIVEN IMPLICATIONS
 - ADAPT FUNCTION IS PART OF THE TOOL
- or ● = Fixed
□ or ○ = Adapter-defined

[illegible]



- COMPLETE DETAILS OF EACH OBSERVATION
- USE SPACECRAFT AND INSTRUMENT CHARACTERISTICS AS WELL AS GEOMETRY, e.g.
 - FIELDS OF VIEW
 - SLEW / TURN RATES AND CONSTRAINTS



- CONVERT SCIENCE, ENGINEERING AND NAVIGATION ACTIVITIES INTO SPACECRAFT "TERMINOLOGY"
- MERGE ALL ACTIVITIES REQUESTED
- EXPAND TO MNEMONIC SPACECRAFT COMMANDS (AND CALLS TO ONBOARD BLOCKS)
- CHECK FLIGHT, MISSION, AND COMMON-SENSE RULES
- PRODUCE MNEMONIC SEQUENCE
- PREDICT SPACECRAFT EVENTS



- **CONSISTS OF SPACECRAFT COMMANDS**
 - **LOW LEVEL (e.g., FLIP SWITCH)**
 - **HIGH LEVEL, DETERMINISTIC (e.g., MOSAIC SLEWS) ("ON-BOARD BLOCKS")**
 - **HIGH LEVEL, STATE-DEPENDENT (e.g., ROVER TRAVERSE) ("BEHAVIORS")**
- **TIME-BASED OR EVENT-DRIVEN**
- **EXECUTED IN REAL TIME OR STORED IN SPACECRAFT MEMORY**



- **WHOLE SEQUENCE UPLINKED AT ONE TIME**
- **STORED IN SPACECRAFT MEMORY**
- **EACH COMMAND EXECUTED BY SPACECRAFT AT SCHEDULED TIME OR EVENT**
- **WHY STORED SEQUENCES?**
 - **ACCOMMODATES DELAYS IN FLIGHT TIME**
 - **USES LESS GROUND STATION**
 - **MAKES EXACT TIMING OF UPLINK TIME UNIMPORTANT**
 - **ALLOWS SPACECRAFT ACTIVITY WHEN NOT VISIBLE OR STATION IS UNAVAILABLE**
 - **CAN VERIFY RECEIPT OF ALL COMMANDS BEFORE EXECUTION OF ANY**
 - **IS A STEP TOWARD AUTONOMOUS SPACECRAFT**



- **TIME FOR MESSAGE TO TRAVEL FROM EARTH TO AND FROM SPACECRAFT**
- **LIMITS GROUND PARTICIPATION IN ACTIVE SPACECRAFT**

TODAY'S ROUND TRIP LIGHT TIME from EARTH

GALILEO		58 minutes
VOYAGER 1	15 hours	13 minutes
VOYAGER 2	11 hours	48 minutes
MAGELLAN		26 minutes
ULYSSES		48 minutes
PIONEER 10	16 hours	35 minutes
PIONEER 11	11 hours	8 minutes

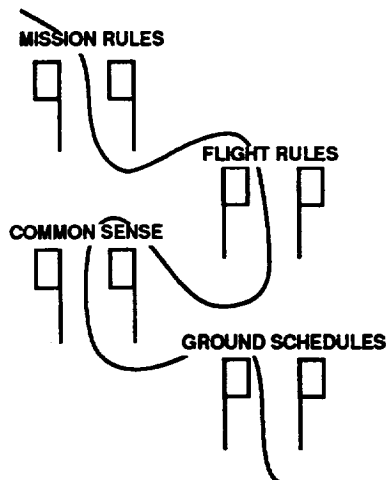


**DEMONSTRATION OF SEQ_GEN FOR PROTOTYPE OF
CASSINI ULTRAVIOLET SPECTROMETER PLANNING**

- **EXPANSION OF SPACECRAFT BLOCKS (MACROS) TO LOW-LEVEL COMMANDS**
- **CONFLICT IDENTIFICATION AND RESOLUTION**
- **GRAPHING OF MODEL ATTRIBUTES**



- GROUPS LOW-LEVEL COMMANDS FOR A HIGH-LEVEL ACTION
- ONE BLOCK YIELDS SEVERAL COMMANDS
 - EITHER A FIXED LIST OF COMMANDS
 - OR GOVERNED BY PARAMETERS AND LOGIC
 - EXAMPLES: MANEUVER, MOSAIC
- EXPANDING COMMANDS CAN BE DONE ON GROUND OR ON SPACECRAFT
- CAN BE REUSED
- DESIGNS OUT CONFLICTS; ENFORCES HOW TO OPERATE SPACECRAFT
- FOSTERS HUMAN-LEVEL THINKING
 - SPACECRAFT CAN EXPAND INTO DEMANDS
 - BLOCKS ARE PRE-TESTED, WHICH ELIMINATES NEED FOR TESTING COMMANDS THAT USE THE BLOCK
- COST INGREDIENTS:
 - SEQUENCING IS CHEAPER TO SEQUENCE AT BLOCK LEVEL
 - TOO EXPENSIVE TO HANDCRAFT EVERY SEQUENCE
 - FEWER AND SIMPLER BLOCKS ARE EASIER TO DESIGN AND TEST



A SEQUENCE MUST PASS MANY RULES GATES



**EXAMPLE RULES AND CONSTRAINTS
CHECKED IN SEQUENCE INTEGRATION**

- PLAY BACK STORED DATA BEFORE IT IS OVERWRITTEN
- DOWNLINK RATE MUST NOT EXCEED LINK CAPABILITY
- TRANSMIT ONLY WHEN TRACKING STATION IS ALLOCATED
- DON'T USE MORE PROPELLANT PER ORBIT THAN ALLOCATED
- COVER INSTRUMENTS BEFORE FIRING THRUSTERS
- DON'T ISSUE TOO MANY COMMANDS AT ONCE - PROCESSOR MAY DROP SOME
- FIRE THE THRUSTERS EVERY 62 DAYS TO CLEAR THE LINES
- DON'T TRY TO SLEW TOO FAST (WILL EXCEED AVAILABLE POWER AND PICTURE WILL SMEAR)
- DON'T TAKE MORE THEN 50K IMAGES - NO BUDGET TO PROCESS EXTRAS
- DON'T MAKE SEQUENCES BIGGER THAN MEMORY ON SPACECRAFT
- DON'T COMMAND AN INSTRUMENT THAT IS OFF (EXCEPT TO TURN IT ON)
- DON'T PUT TOO MUCH DATA ON THE BUS AT ONCE
- DON'T TURN WITHIN 30° OF SUN FOR MORE THAN ONE HOUR

**SOME RULES DISAPPEAR OR SIMPLIFY WITH MARGINS AND
PRE-ALLOCATION OF TIME AND RESOURCES**

**SEQ_GEN**

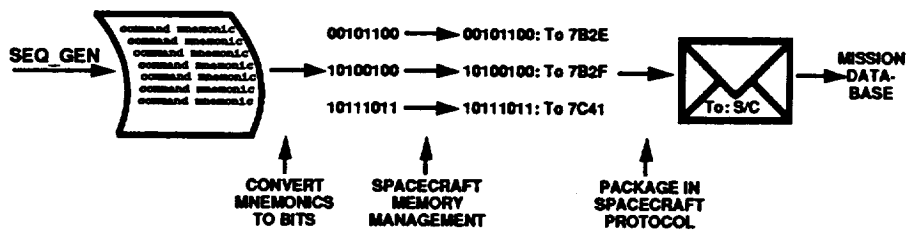
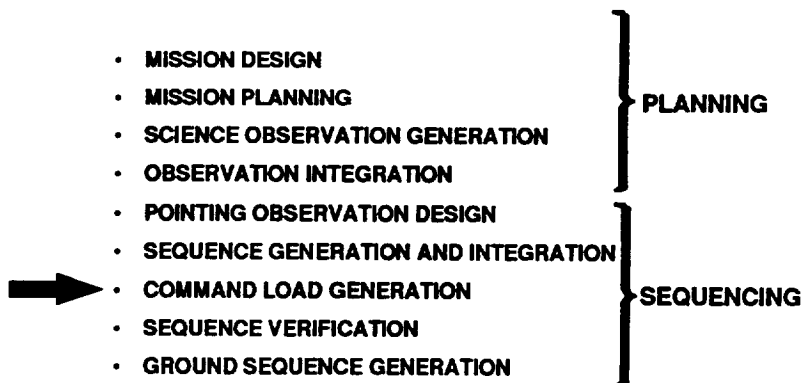
- ☐ KNOWS MNEMONIC SPACECRAFT COMMANDS, BLOCKS, MODELS AND RULES
- EXPANDS BLOCKS TO COMMANDS
- MODELS EFFECT ON SPACECRAFT, CHECKS RULES
 - PREDICTIONS ARE ARED IN SPICE KERNELS
 - PREDICTIONS MAY BE NEEDED TO ANALYZE ANOMALIES
- SHOWS VIOLATIONS
- IS USER INTERACTIVE

■ or ● = No adaptation required
□ = Requires adaptation



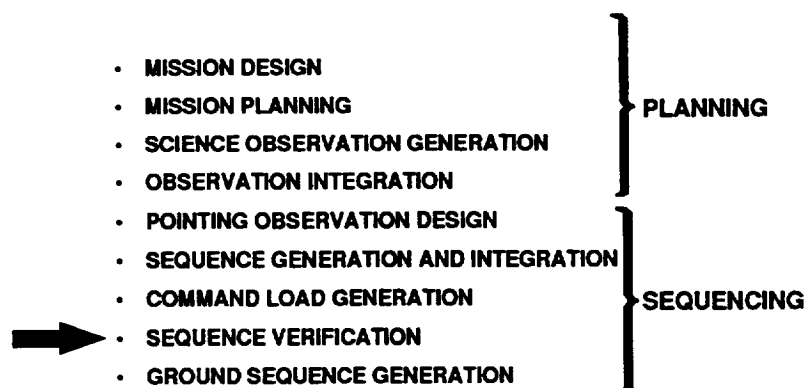
OCOR





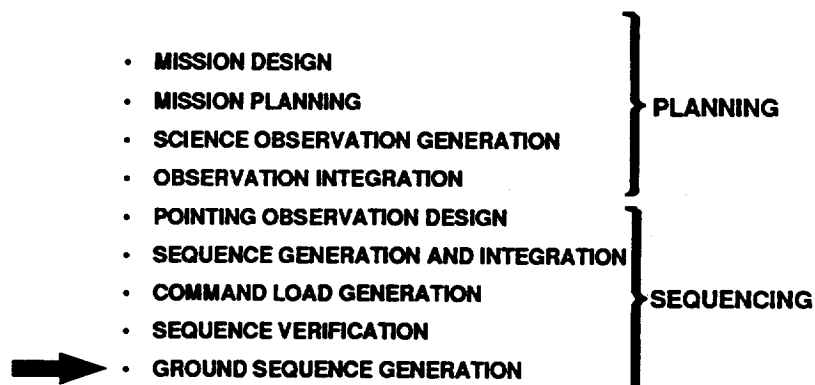
- **JPL HAS MULTIMISSION CAPABILITY**
 - **COST SAVINGS HINTS:**
 - **USE CCSDS * STANDARDS**
 - **USE "COMMAND DATABASE" TO EXPRESS COMMANDS**
 - **INITIALLY AND FOR UPDATES**
 - **DIRECTS MULTIMISSION SOFTWARE**
 - **USE SIMPLE MEMORY MANAGEMENT SCHEME**
 - **ONGROUND OR ONBOARD**

* CCSDS: Consultative Committee for Space Data Systems



- A BIT-LEVEL SIMULATOR IS SOFTWARE THAT SIMULATES THE PROCESSING OF THE SEQUENCE BY THE SPACECRAFT
 - USES BINARY FLIGHT SOFTWARE
 - USES BINARY COMMAND LOAD
- BIT-LEVEL SIMULATION MAY BE DESIRABLE FOR
 - CHECKING SEQUENCES
 - TESTING FLIGHT SOFTWARE
- JPL HAS MULTIMISSION CAPABILITY
 - ADAPTER SUPPLIES MODELING MODULES
 - COST SAVINGS HINT:
 - 1750A PROCESSOR SIMULATION MODULES BEING IMPLEMENTED

■ or ● = No adaptation required
 □ or ○ = Requires adaptation



- **CREATE SCHEDULES FOR GROUND ACTIONS TO SUPPORT SPACECRAFT ACTIVITY**
- **GENERATE SEQUENCE OF EVENTS (GROUND INTEGRATED WITH SPACECRAFT)**
- **DEEP SPACE NETWORK (DSN) CONFIGURATION COMMANDS AND SCHEDULE**
- **PREDICTED TELEMETRY**

**DEMONSTRATION OF SEG AND SEG SHELL FOR
MARS OBSERVER**

- **SEG HELPING USER CHOOSE INPUT FILES**
- **CHOOSE SUBPROCESSES TO EXECUTE**
- **VIEW SEQUENCE OF EVENTS**
- **VIEW DSN KEYWORDS FILE**

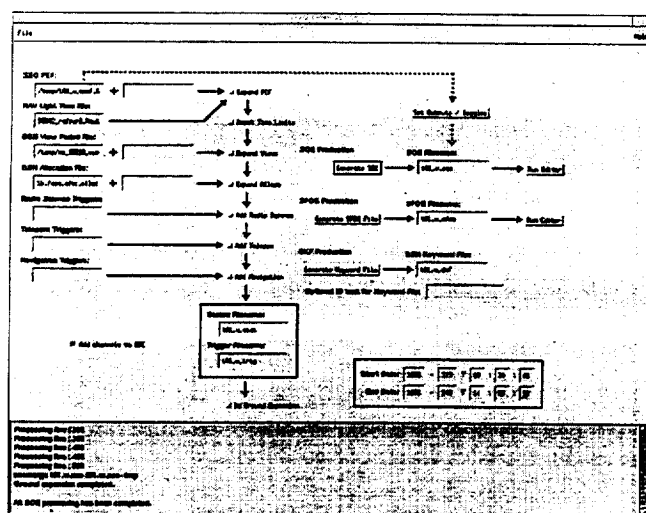


- PRESENTS FILE NAMES, LETS USER CHOOSE OR OVERWRITE FILES
- ALLOWS USER SELECTION OF FUNCTIONS TO EXECUTE

☐ ADAPTER CAN BE CONFIGURED TO CONTROL OTHER PROGRAMS

■ or ● = No adaptation required

□ or ○ = Requires adaptation



ORIGINAL PAGE IS
OF POOR QUALITY

- **DERIVE DSN CONFIGURATION COMMANDS / SCHEDULE FROM SPACECRAFT SEQUENCE**
 - **BASED ON ADAPTER-SUPPLIED TABLES**
 - **WRITES "DSN KEYWORD FILE"**
- **DERIVES TELEMETRY PREDICTIONS FROM SEQUENCE COMMANDS**
 - **BASED ON ADAPTER-SUPPLIED TABLES**
- **DISPLAYS SPACE FLIGHT OPERATIONS SCHEDULE**
- **HAS USER INTERACTIVE EDITOR**
 - **EXTRACTS OR HIGHLIGHTS SUBSETS**
 - **PUTS CHANGE BARS**

■ or ● = No adaptation required

□ or ○ = Requires adaptation

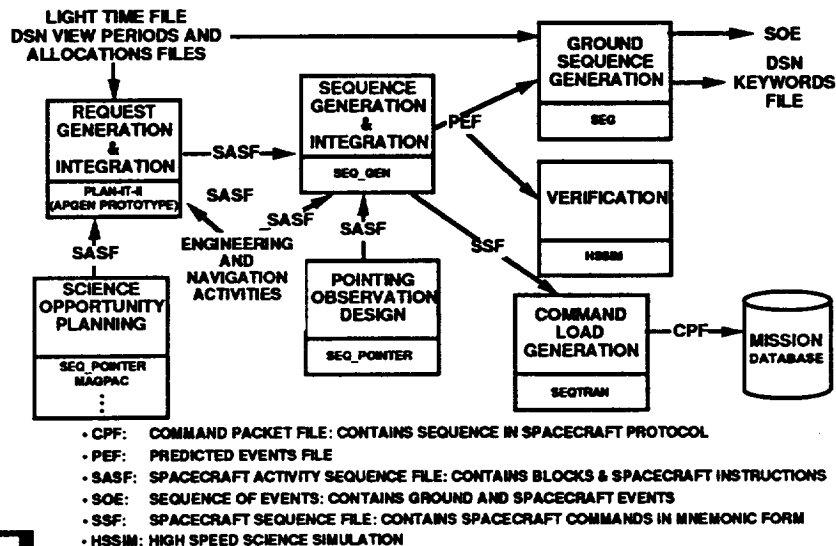
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- **MISSION DESIGN**
 - PRE-LAUNCH
 - DESIGN TRAJECTORY
- **MISSION PLANNING**
 - MISSION PLAN, HIGH-LEVEL TIMELINES
 - MISSION RULES, GUIDELINES, CONSTRAINTS
 - CONTINGENCY PLANS
- **SCIENCE OBSERVATION GENERATION**
 - PLAN OBSERVATIONS BASED ON GEOMETRY AND EPHEMERIDES
- **OBSERVATION INTEGRATION**
 - MERGE SCIENCE, ENGINEERING, AND NAVIGATION ACTIVITIES
 - MODEL ATTRIBUTES OF INTEREST TO SCIENTISTS, PLUS KEY LIMITED OR SHARED RESOURCES
 - RESOLVE CONFLICTS
- **POINTING OBSERVATION DESIGN**
 - ADD DETAILS, USING KNOWLEDGE OF SPACECRAFT
 - FIELDS OF VIEW
 - ABILITY TO DO TURNS
 - ABILITY TO MOVE SCAN PLATFORM



- **SEQUENCE GENERATION AND INTEGRATION**
 - EXPAND TO MNEMONIC INSTRUCTIONS CORRESPONDING TO ONES UNDERSTANDABLE BY SPACECRAFT
 - MERGE ENGINEERING AND SCIENCE
 - CHECK RULES: FLIGHT, MISSION, COMMON SENSE
- **COMMAND LOAD GENERATION**
 - TRANSLATE MNEMONICS TO BITS
 - MANAGE SPACECRAFT MEMORY
 - PACKAGE INTO SPACECRAFT PROTOCOL
- **VERIFICATION**
 - SIMULATE EXECUTION BY FLIGHT SOFTWARE OF THE COMMAND LOAD
- **GROUND SEQUENCE GENERATION (UPLINK MISSION CONTROL)**
 - PLAN COORDINATED GROUND ACTIVITIES, SUCH AS DSN





- DEFINE SPACECRAFT CHARACTERISTICS RELATED TO POINTING (e.g., FIELDS OF VIEW, TURN RATES, CONSTRAINTS, MOSAIC) (TABLES + C)
- IDENTIFY KEY, HIGH-LEVEL LIMITED OR SHARED RESOURCES; BUILD MODELS INTO PLANNING SOFTWARE (TABLES)
- DEVELOP AUTOMATED SCHEDULING STRATEGIES, ADD TO PLANNING SOFTWARE (LISP)
- DEFINE SPACECRAFT COMMANDS, PUT INTO COMMAND DATA BASE (LITTLE LANGUAGE)
- DEFINE BLOCKS, PUT INTO SEQUENCING SOFTWARE (LITTLE LANGUAGE)
- DEFINE FLIGHT AND MISSION RULES – BUILD SEQUENCING SOFTWARE MODELS TO CHECK (SOME OF) THE RULES (TABLES, LITTLE LANGUAGE, C OPTIONAL)
- DEFINE SPACECRAFT MEMORY MANAGEMENT (WHETHER IT IS DONE ONBOARD OR ON THE GROUND) – PUT IT INTO SOFTWARE
 - MACROS (IF ON GROUND)
- DEFINE COMMAND/TELEMETRY RELATIONSHIPS (TABLES)
- DEFINE SPACECRAFT ACTION IMPLICATIONS ON DSN ACTIVITY (TABLE)
- DEFINE PROGRAM CONTROL SHELL



- **USE EXISTING MULTIMISSION SOFTWARE**
 - CHEAPER TO ADAPT THAN TO BUILD NEW
 - REDUCTION OF MAINTENANCE COSTS BY AMORTIZATION OVER MULTIPLE PROJECTS
 - APPLICABLE TO SIMPLE AND COMPLEX MISSIONS
 - ADDITIONAL CAPABILITY IN RESERVE (FALLBACK)
- **MINIMIZE PAPER INPUTS / INTERFACES**
- **FOLLOW STANDARDS**
 - CCSDS TELECOMMAND
 - FILE FORMATS
 - IEEE FLOATING POINT
 - CRC / CHECKSUM
 - SIMPLE SPACECRAFT CLOCK



- **DESIGN SPACECRAFT, MISSION, AND OPERATIONS CONCURRENTLY**
 - USE MARGINS IN SPACECRAFT TO AVOID OPERATIONS COMPLEXITY
 - PLAN TO AVOID CONFLICT: ALLOCATIONS AND BLOCKS
- **USE INTERPLANETARY MISSION EXPERIENCE OF JPL**
- **IF CCSDS STANDARDS ARE FOLLOWED AND SPACECRAFT INFORMATION IS AVAILABLE, A BASIC UPLINK GROUND SYSTEM CAN BE MADE AVAILABLE IN THREE TO SIX MONTHS**





PARTNERSHIP OPTIONS: JPL WITH SELECTED PRINCIPAL INVESTIGATORS

- **UPLINK OPERATIONS SYSTEM**
 - **PLANNING / EXECUTION**
 - **PEOPLE**
 - **SOFTWARE**
- **UPLINK SOFTWARE SYSTEM**
 - **DESIGN**
 - **ADAPTATION**
 - **MAINTENANCE: ACCESS TO UPGRADES**
- **UPLINK COMPONENTS**
 - **OPERATIONS**
 - **ADAPTED SOFTWARE**



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ACKNOWLEDGEMENTS

TODAY'S DEMONSTRATIONS ARE PRESENTED BY THE FOLLOWING PEOPLE:

POINTER: Jeff Boyer, POWTER Cognizant Engineer

Plan-IT-II: Curt Eggemeyer, Plan-IT-II Researcher and Developer
Stephen Peters, Concept and Adaptation for Plan-IT-II's application to EOS

SEQ_GEN: Jose Salcedo, SEQ_GEN Cognizant Engineer

SEG: William Heventhal III, SEG Cognizant Engineer

Command Tool Kit: Jeff Biesladecki, Cognizant Engineer
Charles Ames, Cognizant Engineer
Cassie Mulnix, Programmer



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- **SEQ_POINTER**
REMOTE SENSING OBSERVATION GENERATION AND DESIGN
- **PLAN-IT-II**
ACTIVITY REQUEST GENERATION AND INTEGRATION
- **SEQ_GEN**
SEQUENCE GENERATION AND INTEGRATION
- **SEG SHELL AND SEG**
SEQUENCE OF EVENTS GENERATOR AND ITS OPERATIONAL SHELL
- **COMMAND TRANSLATION TOOL KIT**
COMMAND MNEMONICS, BIT PATTERNS, AND CORRESPONDING
TELEMETRY



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MISSION DATA TRANSPORT and DELIVERY

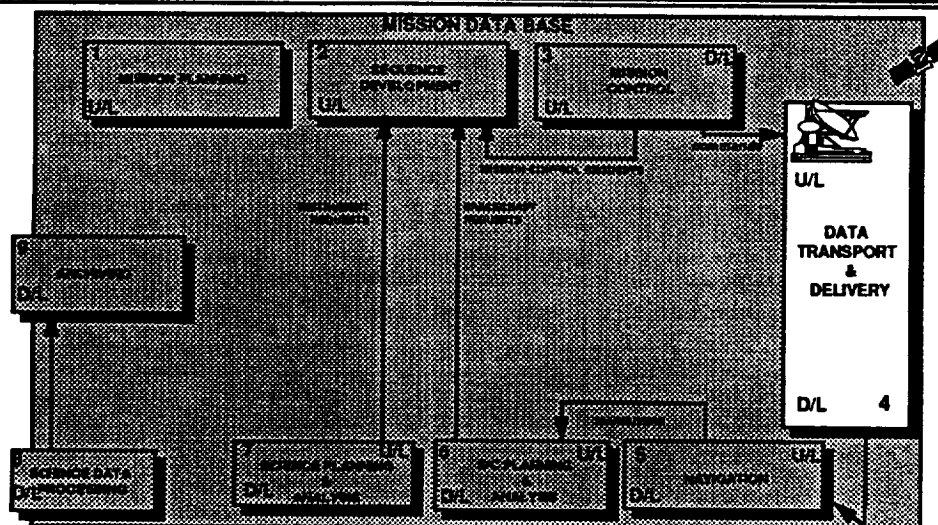
Robert E. Edelson
Functional Area Manager: Telemetry
Multimission Operations Systems Office



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MISSION DATA TRANSPORT AND DELIVERY

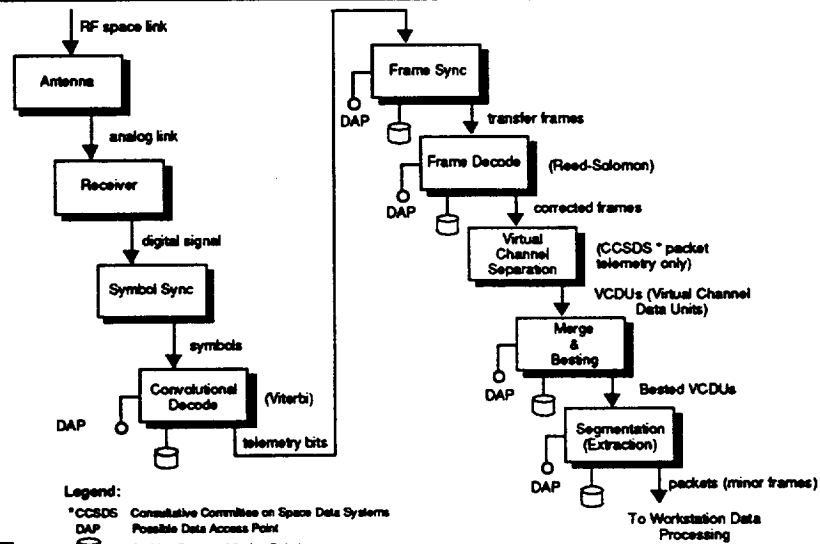


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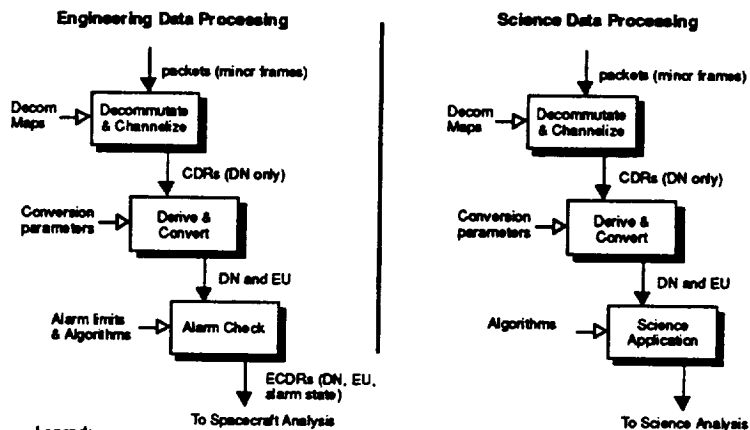
REE - 2

OUTLINE

- **DATA TRANSPORT PROCESS**
- **DSN MISSION SUPPORT**
 - DSN MISSION SUPPORT FUNCTIONS
- **DATA SYSTEM OPERATIONS MISSION SUPPORT**
 - TELEMETRY DATA PROCESSING DEMONSTRATION
 - DATA TRANSPORT FUNCTIONS
 - ON-LINE STORAGE CONTENT
 - DATA QUERY DEMONSTRATION
- **PERFORMANCE**
- **HOW TO REDUCE COST**
- **MARS PATHFINDER DEMONSTRATION**
- **CONCLUSION**

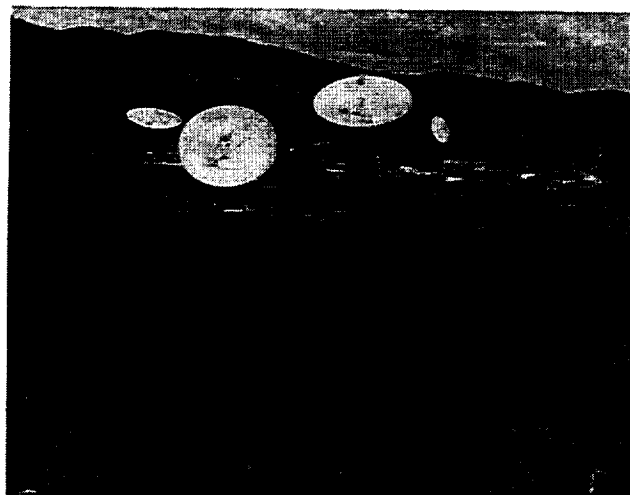


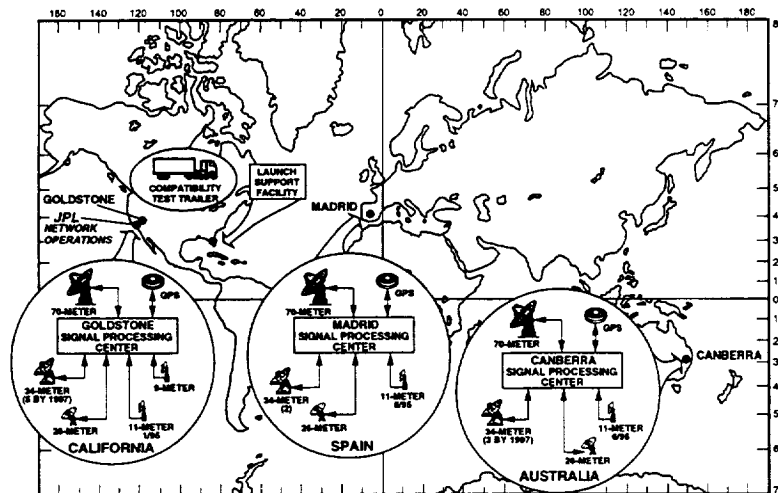
Workstation Data Processing



Legend:

CDR Channelized Data Record
 DN Data Number
 EU Engineering Units
 ECOR Expanded Channelized Data Record





- **ACQUIRE TELEMETRY DATA FROM SPACECRAFT AND PROVIDE IT TO FLIGHT PROJECTS**
- **ACCEPT COMMAND DATA FROM FLIGHT PROJECTS, TRANSMIT COMMANDS TO SPACECRAFT, AND CONFIRM COMMAND TRANSMISSIONS**
- **WHEN REQUIRED, GENERATE RADIOMETRIC, RADIO SCIENCE, AND VERY LONG BASELINE INTERFEROMETRY (VLBI) DATA FOR FLIGHT PROJECTS AND OTHER USERS**
- **GENERATE PREDICTIONS FOR SIGNAL ACQUISITION**
- **SCHEDULE COMMUNICATIONS WITH SPACECRAFT**
- **PARTICIPATE WITH FLIGHT PROJECTS IN THEIR TEST AND TRAINING**
 - **COMPATIBILITY TEST TRAILER AVAILABLE FOR TEST SUPPORT AT REMOTE SITES**

Further information is available in the DSN document:
DSN Support of Earth Orbiting and Deep Space Missions



JPL DATA SYSTEMS OPERATIONS MISSION SUPPORT



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TELEMETRY DATA PROCESSING DEMONSTRATION

- AUTOMATIC CONFIGURATION AND INITIATION OF OPERATIONS
- ESTABLISHING INTERFACE WITH DEEP SPACE NETWORK
- INITIATION OF TELEMETRY INPUT AND DATA STREAM PROCESSING
- INITIATION OF ON-LINE STORAGE AND ESTABLISHING DATA ROUTING
- INITIATION OF WORKSTATION DISPLAYS AND REAL-TIME PROCESSING OF DATA FOR VOYAGER, ULYSSES, AND GALILEO (AS AVAILABLE)



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TELEMETRY DATA PROCESSING DEMONSTRATION (continued)

- **USER WORKSTATION CAPABILITIES**
 - DATA NUMBER / ENGINEERING UNITS CONVERSION
 - DERIVED CHANNELS
 - ALARM LIMIT CHECKING
 - PRESENTATION TOOLS FOR CHANNEL VALUE DISPLAY:
 - TABULAR DISPLAYS (TEXT)
 - DATA FLOW DISPLAYS
 - CHANNEL vs. TIME DISPLAYS
 - CHANNEL vs. CHANNEL DISPLAYS



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DATA TRANSPORT FUNCTIONS

- INTERFACE WITH DEEP SPACE NETWORK (DSN) FACILITIES TO RECEIVE SPACECRAFT TELEMETRY AND GROUND MONITOR DATA
- TRANSFER OF COMMAND FILES TO THE DSN FOR RADIATION TO THE SPACECRAFT
- DATA CAPTURE AND STAGING
 - SPACECRAFT/INSTRUMENT TELEMETRY DATA
 - GROUND SYSTEM PERFORMANCE DATA
- TELEMETRY PROCESSING
 - FRAME SYNCHRONIZATION
 - PACKET EXTRACTION
 - CHANNELIZATION
 - ERROR CORRECTION
 - TIME ORDERING
 - DATA RECALL
 - DATA BESTING

■ or ● No adaptation required

□ or ○ Requires adaptation to project needs



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☐ **ON-LINE STORAGE**

- ☐ ON-LINE DATA STORAGE IN EACH PROJECT'S DATABASE (VARIABLE DEPENDING ON PROJECT NEED, TYPICALLY PROVIDE 32 GBYTES OF ON-LINE STORAGE)
- ☒ EACH PROJECT'S DATABASE SUPPORTS OVER 25 SIMULTANEOUS QUERIES

☒ **DATA DISTRIBUTION**

- ☒ NEAR-REAL-TIME OR NONREAL-TIME
- ☒ AUTOMATED OR ON DEMAND
- ☒ LOCAL OR REMOTE

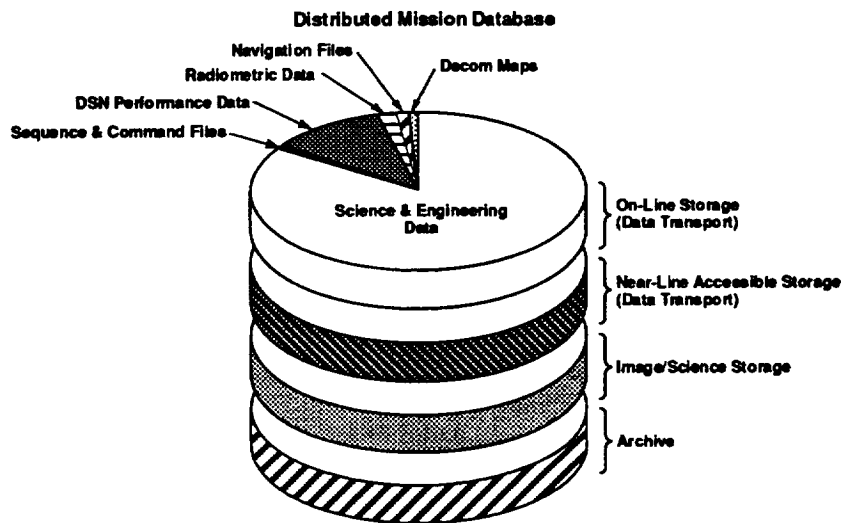
☐ **SECURE REMOTE ACCESS VIA SCIENCE OPERATIONS PLANNING COMPUTERS (SOPC's) FROM PRINCIPAL INVESTIGATOR'S FACILITY (CAN DO ANALYSIS WHEREVER NEEDED)**

- ☒ or ☒ No adaptation required
☐ or ☐ Requires adaptation to project needs


ON-LINE STORAGE EXAMPLES:

Spacecraft	Highest Data Rate (bps)	Nominal Data Rate (bps)	Storage Capacity (Gbytes)	Amount of Data Stored (Days)
Voyager 1	1.4K	160	2.4	180
Voyager 2	7.2K	600		180
Ulysses	40K	8192	2	60
Galileo	40	16	6	240
Mars Observer	85K	Variable	32	100
Discovery Possibilities	1K - 100K	Variable	2 - 40	~100





☒ **SYSTEM MONITOR AND CONTROL**

☐ **TEST AND TRAINING SUPPORT**

- ☐ DATA SIMULATION
- ☒ SYSTEM TEST AND INTEGRATION
- ☒ SUPPORT FOR USER ACCEPTANCE TESTING
- ☐ SUPPORT DURING FLIGHT SYSTEM TESTING (TEST TELEMETRY AND COMMAND SYSTEM)

☒ or ☒ No adaptation required

☐ or ☐ Requires adaptation to project needs



0-2

(How to examine spacecraft data)

WORKSTATION EXAMPLE:

- INITIATING DATA ACCESS AND ESTABLISHING DATA ROUTING
- INITIATING WORKSTATION DISPLAYS AND PROCESSING DATA FOR VOYAGER, ULYSSES, AND GALILEO (AS AVAILABLE)
- TYPES OF QUERIES:
 - PROVIDE DATA¹ "FROM NOW ON"
 - PROVIDE DATA¹ "FROM TIME 'A' ON"
 - PROVIDE DATA¹ IN RANGE FROM TIME 'A' TO TIME 'B'
 - PROVIDE CHANNEL 'X' DATA FROM TIME 'A' TO TIME 'B'

PERSONAL COMPUTER EXAMPLE:

- DEMONSTRATION OF INTERFACE TO A MAC
 - LOW COST PC's OR MAC's CAN BE AND HAVE BEEN USED TO PROCESS AND DISPLAY INSTRUMENT DATA



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¹ Data types defined by Project

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- GROUND PROCESSING OF SPACECRAFT TELEMETRY DATA

DATA RATE	TYPES OF PROCESSING
10 bps to 224 Kbps	Real-Time (Spacecraft to On-Line Storage)
Up to ~ 500 Kbps	Multiple data streams or Direct connection
> 500 Kbps *	Data System Adaptation Required

- DATA SYSTEMS OPERATIONS SUPPORT UP TO 24-HOURS PER DAY, 7-DAYS PER WEEK (AS NEGOTIATED WITH PROJECT)
- LOW LATENCY FOR DATA ACCESS - DATA AVAILABLE IN "REAL-TIME" AFTER RECEIPT AT JPL (TYPICALLY THE TIME REQUIRED TO FRAME SYNC THREE FRAMES)
- TIME-ORDERED, COMPLETE DATA SET

* DSN to 900 Kbps



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- **ADAPT EXISTING SYSTEM VS DEVELOP A NEW SYSTEM**
- **USE STANDARDS (e.g., CCSDS¹) FOR LOWEST COST ADAPTATION**
 - **ADAPTATION BY TABLE UPDATES**
 - **90% OR MORE OF PROJECT REQUIREMENTS ARE MET BY EXISTING SYSTEM (MARGINAL COST FOR ADDING A MISSION IS SMALL, e.g., DEVELOPMENT FOR MARS PATHFINDER PROJECT LESS THAN \$0.5M)**
- **REDUCE OPERATIONS AND MAINTENANCE COSTS THROUGH SHARING WITH OTHER MISSIONS (BASELINE SUPPORT NOT CHARGED TO PROJECTS)**
- **DEFINE AND ENFORCE SYSTEM AND DATA SECURITY RULES**

¹CCSDS: Consultative Committee for Space Data Systems



- **FOLLOW STANDARDS (ONE PATH THROUGH THE STANDARDS):**
 - **FOLLOW CCSDS TRANSFER FRAME FORMATS**
 - **USE THE CCSDS UNSEGMENTED SPACECRAFT CLOCK**
 - **USE ONE TRANSFER FRAME FORMAT**
 - **USE VARIABLE LENGTH PACKETS THAT FOLLOW THE CCSDS STANDARD**
 - **HAVE EACH PACKET TIME-TAGGED WITH THE SPACECRAFT CLOCK AT THE BEGINNING OF THE PACKET**
 - **DEFINE ALL THE PACKET IDENTIFIERS EARLY**
 - **USE THE IEEE STANDARDS FOR FLOATING POINT VALUES INSIDE THE PACKETS**
 - **USE CCSDS STANDARD ALIGNMENT AND PACKING RULES (NON-VAX, IBM) STRUCTURE**
(IF CCSDS STANDARDS ARE FOLLOWED AND SPACECRAFT INFORMATION IS AVAILABLE, A BASIC GROUND DATA SYSTEM CAN BE OPERATING IN LESS THAN THREE MONTHS)
- **THE MORE INFORMATION ABOUT THE DATA AND THE EARLIER IT IS DEFINED, THE BETTER AND CHEAPER THE SYSTEM!**



- **MINIMIZE CHANGES IN REQUIREMENTS OR DESIGN**
- **USE DATA RATES WITHIN DSN CAPABILITIES**
- **OPTIMIZE ON-LINE STORAGE REQUIREMENTS**
 - **TRADEOFF BETWEEN HARDWARE AND OPERATIONS COMPLEXITY**
- **INVOLVE GROUND SYSTEM EARLY IN FLIGHT SYSTEM DESIGN AND DEVELOPMENT (e.g., TEST TELEMETRY AND COMMAND SYSTEM)**
- **PROVIDE CLOSE SUPPORT TO GROUND SYSTEM TESTERS (e.g., COMBINED TEST TEAM); PARTICIPATE IN GDS TESTING EARLY**



- **PROVIDES INTEGRATED GROUND DATA SYSTEM PROCESSING SUPPORT**
 - **SPACECRAFT (OR SYSTEM TESTBED) INTERFACE**
 - **DATA CAPTURE AND STAGING**
 - **DATA DISTRIBUTION AND DISPLAY**
- **SUPPORT FOR SIMULTANEOUS FLIGHT AND GROUND SOFTWARE DEVELOPMENT**
- **SPACECRAFT ASSEMBLY, TEST, LAUNCH OPERATIONS (ATLO) TEST SUPPORT**
- **SPACECRAFT FLIGHT SYSTEM TESTBED SUPPORT (POST-LAUNCH)**



- **INITIATE MARS PATHFINDER GROUND DATA SYSTEM SOFTWARE**
 - INTERFACE WITH SPACECRAFT SOFTWARE
 - INITIALIZE TELEMETRY PROCESSING
 - USER DISPLAYS
- **SIMULATION OF SOL 1 ENTRY, DESCENT, AND LANDING (FIRST DAY ON MARS)**
 - RECEIPT OF ENGINEERING DATA FOR ENTRY, DESCENT, AND LANDING
 - RECEIPT OF PANORAMA DATA
 - RECEIPT OF ROVER DATA
- **DEMONSTRATION OF CHANNEL DEFINITION**
- **DEMONSTRATION OF EXCEL USE FOR MARS PATHFINDER DATA**



- **GROUND DATA SYSTEM ELEMENTS ARE FULLY INTEGRATED (INCLUDING COMMAND [UPLINK], DEEP SPACE NETWORK, AND PLANETARY DATA SYSTEM)**
- **SYSTEM IS PROVEN FOR MISSIONS OF ALL SIZES**
 - SMALL MISSIONS (e.g., VOYAGER INTERSTELLAR MISSION, MAGELLAN GRAVITY MAPPING, MARS PATHFINDER)
 - MODERATE MISSIONS (e.g., MARS OBSERVER)
 - LARGE MISSIONS (e.g., GALILEO, CASSINI)



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MISSION COORDINATION and ENGINEERING ANALYSIS

Michael H. Hill

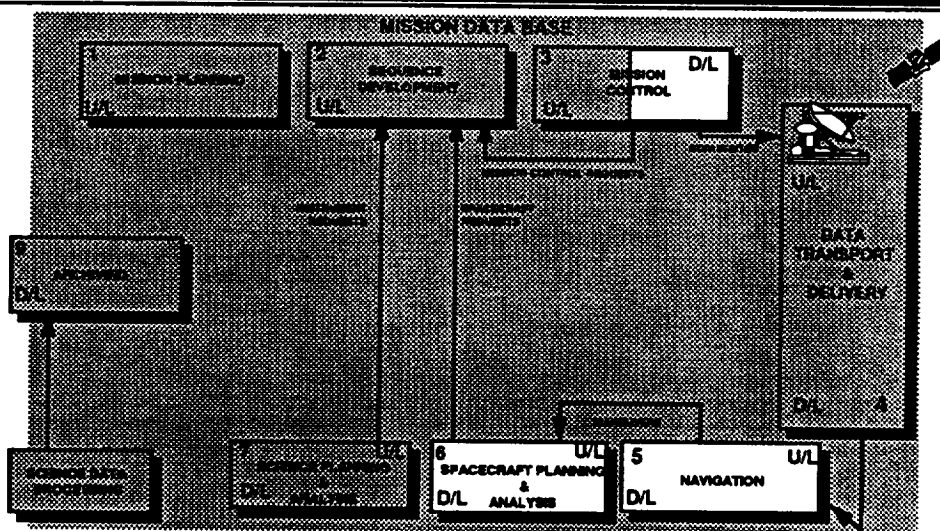
Functional Area Manager: Spacecraft Analysis
Multimission Operations Systems Office



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MHH - 1

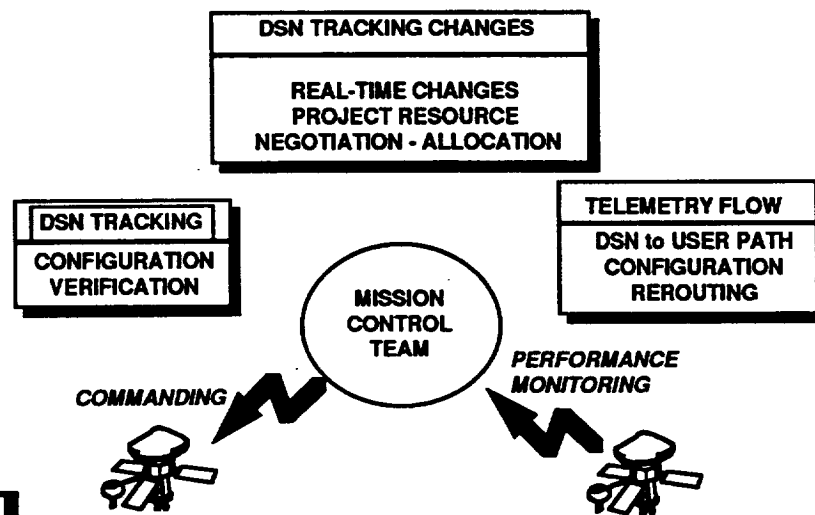
MISSION COORDINATION AND ENGINEERING ANALYSIS

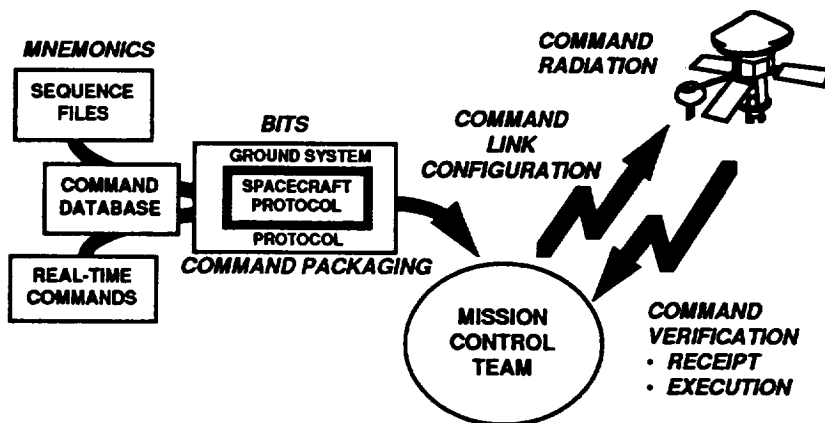


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MHH - 2

- MISSION COORDINATION
- NAVIGATING THE SOLAR SYSTEM
- UNDERSTANDING THE SPACECRAFT

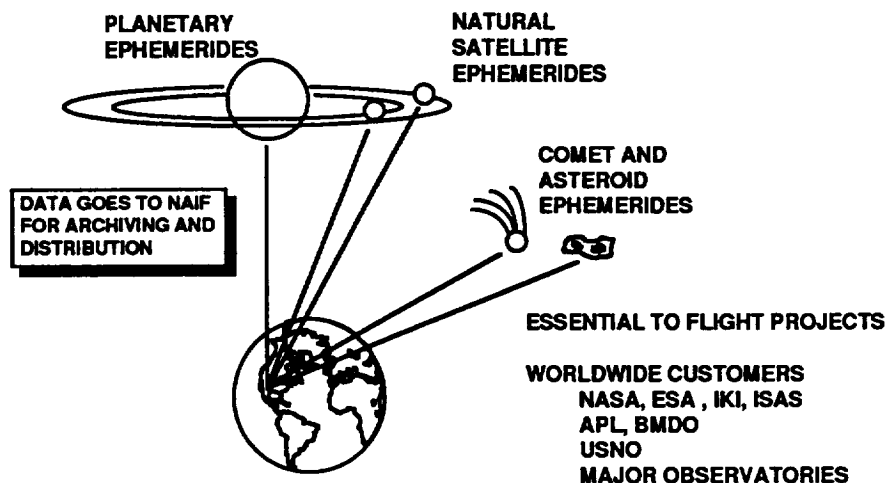


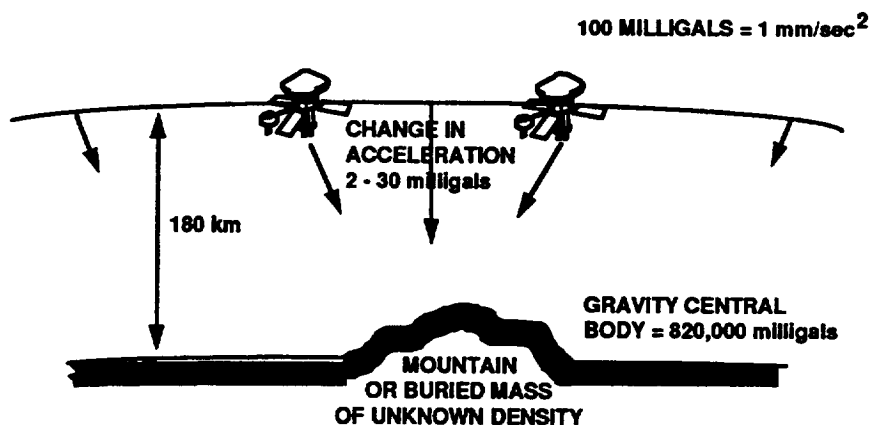
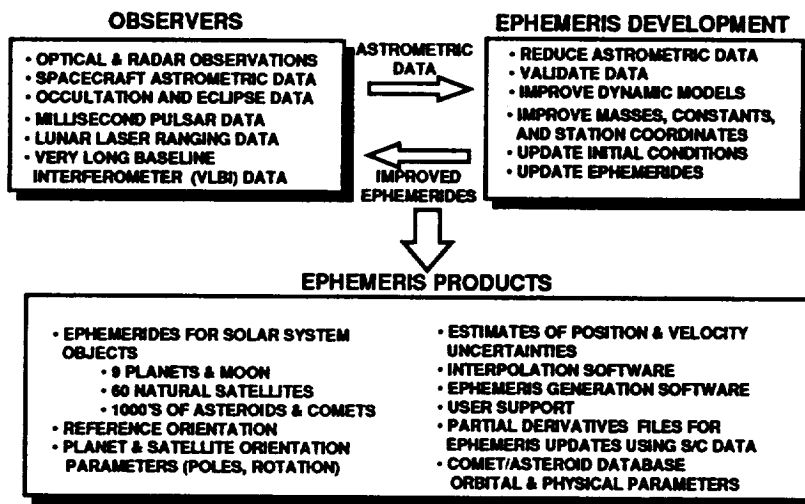


- MISSION COORDINATION
- ➔ • NAVIGATING THE SOLAR SYSTEM
- UNDERSTANDING THE SPACECRAFT



- **EPHEMERIDES OF CELESTIAL BODIES**
- **GRAVITY MODELING**
- **NAVIGATION PLANNING**
- **ORBIT DETERMINATION**
 - **OPTICAL NAVIGATION**
 - **RADIOMETRIC**
- **MANEUVER AND TRAJECTORY ANALYSIS**
- **NAVIGATION ANCILLARY INFORMATION FACILITY (NAIF)**
 - **SPICE INFORMATION SYSTEM**





- **PERFORM NAVIGATION ANALYSIS OF MISSION OPTIONS AS REQUIRED**
- **ASSESS NAVIGATION CAPABILITY IN TERMS OF DELIVERY, KNOWLEDGE ACCURACIES AND PROPELLANT USAGE**
- **SUPPORT THE UPLINK DESIGN FOR NAVIGATION ISSUES**
- **PLAN RADIOMETRIC TRACKING AND OPTICAL NAVIGATION SCHEDULES**



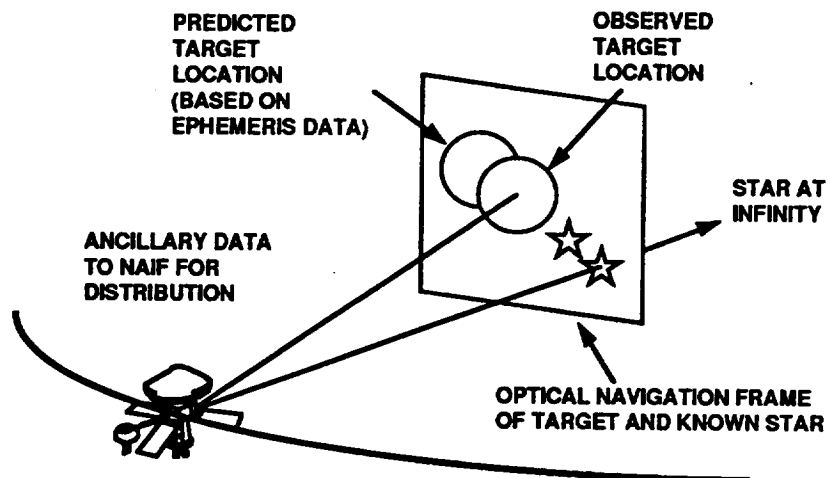
- **COMBINATION OF ENGINEERING DISCIPLINES**
 - ORBITAL MECHANICS
 - SPACECRAFT DYNAMICS
 - TRACKING SYSTEM CHARACTERISTICS
 - STATISTICAL ESTIMATION AND FILTERING THEORY
- **SPACECRAFT TRAJECTORY IS NUMERICALLY INTEGRATED TO A PRECISION CONSISTENT WITH PROJECT REQUIREMENTS**
 - **CONSIDERS NON-GRAVITATIONAL ACCELERATIONS**
 - ATTITUDE STABILIZATIONS THRUSTER FIRINGS
 - SOLAR RADIATION
 - ATMOSPHERIC DRAG - ETC.
- **RADIOMETRIC OBSERVABLES COMPUTED BASED ON GEOMETRY AND DYNAMICS BETWEEN TRACKING STATIONS AND THE INTEGRATED SPACECRAFT TRAJECTORY**
 - ACCOUNTS FOR EARTH ORIENTATION AND TRACKING STATION MOTIONS (PRECESSION, NUTATION, ROTATION, TIDES, PLATE MOTION)
 - DETAILED MODELING OF THE RADIOMETRIC OBSERVABLE



- **RADIOMETRIC AND OPTICAL NAVIGATION DATA IS CONDITIONED TO REMOVE "BAD DATA" AND PREPARE THE DATA FOR THE OD PROCESS**
- **ESTIMATION AND FILTERING PROCESSES HAVE BEEN DEVELOPED TO HANDLE THE SPECIFIC ACCURACY REQUIREMENTS FOR OD**

OD SOFTWARE

- **ORBIT DETERMINATION IS A COMPUTER-INTENSIVE ACTIVITY**
 - SERIES OF PROGRAMS TO PERFORM THE ABOVE ACTIVITIES
 - JPL SYSTEM HAS 1,000,000 LINES OF CODE
 - HERITAGE BACK TO THE EARLY 1970's
 - EXECUTED ON UNIX WORKSTATIONS
- **TYPICALLY MINOR MODIFICATIONS FOR ADAPTATION TO A NEW MISSION**
 - MODULAR, WELL-DOCUMENTED CODE
 - STANDARD INTERFACES



- DESIGN AND ANALYSIS
- MANEUVER IMPLEMENTATION
- REAL-TIME MONITORING
- MANEUVER RECONSTRUCTION
- TRAJECTORY-RELATED PRODUCTS
 - USED BY BOTH ENGINEERING AND SCIENCE IN MISSION OPERATIONS

**ANCILLARY DATA**

- LOCATION, ORIENTATION, SIZE, AND SHAPE OF TARGET BODIES
- LOCATION AND ORIENTATION OF THE SPACECRAFT AND ITS SCIENCE INSTRUMENTS
- LOG OF INSTRUMENT AND SPACECRAFT COMMANDS, AND GROUND DATA SYSTEM ACTIVITIES

USERS

- VOYAGER, MAGELLAN, GALILEO, CLEMENTINE, HUBBLE SPACE TELESCOPE, MARS 94, RADIOASTRON, CASSINI, MARS PATHFINDER

SPICE ANCILLARY INFORMATION SYSTEM IS USED FOR

- EVALUATION OF MISSION DESIGN FROM A SCIENCE PERSPECTIVE
- OBSERVATION PLANNING FOR ONBOARD INSTRUMENTS
- INTERPRETATION OF SCIENTIFIC OBSERVATIONS



ADVANTAGES OF USING THE SPICE SYSTEM

- MATURE, PROVEN APPROACH THAT REQUIRES MINOR MISSION-SPECIFIC ADAPTATIONS
- THE P.I.'s STAFF MAY ALREADY BE FAMILIAR WITH SPICE FROM PREVIOUS WORK
- EASE OF ARCHIVING, SINCE SPICE IS NASA'S STANDARD FOR ARCHIVING ANCILLARY DATA FROM PLANETARY MISSIONS IN THE PLANETARY DATA SYSTEM (PDS)
- COMES WITH A NAVIGATION ANCILLARY INFORMATION FACILITY (NAIF) TOOLKIT FOR ACCESSING AND MANIPULATING THE SPICE DATA
- FACILITATES CORRELATION OF DATA ACROSS MULTIPLE MISSIONS AND INSTRUMENTS
- COMES WITH GOOD DOCUMENTATION
 - WRITTEN FOR THE OUTSIDE USER



EPHEMERIDES	NO ADAPTATION REQUIRED ADHERE TO INTERFACE SPECIFICATIONS FOR THE EPHEMERIDES FILES
ORBIT DETERMINATION	DEVELOPMENT REQUIRED FOR NEW DATA TYPES NO ADAPTATION REQUIRED FOR STANDARD SET OF OD PARAMETERS
TRAJECTORY ANALYSIS	ADAPTATION REQUIRED TO ACCOMMODATE NON-GRAVITATIONAL MODELS DEPENDING ON THE SPACECRAFT CHARACTERISTICS
MANEUVER ANALYSIS	ADAPTATION REQUIRED TO MODEL THRUSTER CONFIGURATIONS AND CHARACTERISTICS AND MISSION CONSTRAINTS ON MANEUVER IMPLEMENTATION
SPICE	MINIMUM ADAPTATION REQUIRED TO INTERFACE THE TELEMETRY DATA AND MISSION SEQUENCING PRODUCTS USING NAIF TOOL KIT





NAVIGATION LOW COST MISSION OPERATIONS CONSIDERATIONS

MISSION DESCRIPTION MINIMIZE THE AMOUNT OF ACTIVITY	NUMBER OF OBSERVATIONS AND TIME BETWEEN OBSERVATIONS NUMBER OF OBSERVATIONS WITH DIFFERENT INSTRUMENTS
ACCURACY REQUIREMENTS MINIMIZE THE DELIVERY ACCURACY TO THE TARGET BODY	REDUCES THE NUMBER OF TRAJECTORY CORRECTION MANEUVERS REQUIRED REDUCES THE AMOUNT OF ORBIT DETERMINATION REQUIRED REDUCES THE AMOUNT OF TRACKING DATA REQUIRED WHICH AFFECTS THE DSN SCHEDULING
SPACECRAFT DESIGN MINIMIZE THE EFFECTS OF NON-GRAVITATIONAL FORCES	USE REACTION WHEELS INSTEAD OF THRUSTERS USE THRUSTERS IN BALANCED PAIRS MINIMIZE THE PROJECTED AREA IMBALANCE TO REDUCE SOLAR PRESSURE TORQUES AND ACCELERATIONS



SPACECRAFT PLANNING AND ANALYSIS

- MISSION COORDINATION
- NAVIGATING THE SOLAR SYSTEM
- ➡ • UNDERSTANDING THE SPACECRAFT



- **REAL-TIME MONITORING OF SPACECRAFT HEALTH**
- **SPACECRAFT HEALTH ASSESSMENT - TREND ANALYSIS**
- **SPACECRAFT RESOURCE MANAGEMENT**
- **MANEUVER DESIGN AND RECONSTRUCTION**
- **INSTRUMENT POINTING AND ENGINEERING CALIBRATIONS**
- **FLIGHT SOFTWARE MAINTENANCE**
- **MULTIMISSION SPACECRAFT ANALYSIS SYSTEM**
 - **A LOOK TO THE FUTURE**



- **VERIFY EXECUTION OF ONBOARD SEQUENCES AND REAL-TIME COMMANDS**
- **MONITOR SPACECRAFT TELEMETRY FOR ALARM VIOLATIONS**
- **MONITOR COMPONENT TRENDS IN REAL TIME**
- **MONITOR TELEMETRY LINK MARGINS**

MISSION CONTROL ANALYSIS SYSTEM**CAN BE USED
ANYWHERE****ADAPTABLE VIA
SCRIPTS****USED FOR BOTH****INSTRUMENTS
ENGINEERING
SUBSYSTEMS**



SPACECRAFT HEALTH AND STATUS TREND ANALYSIS

- SCIENCE INSTRUMENT
 - POWER
 - THERMAL PROFILES
 - MODE AND CONFIGURATION CHANGES
- PROPULSION
 - THRUST LEVEL
- TELECOM
 - PREDICTED VS ACTUAL LINK MARGINS
- SPACECRAFT STATE TRACKING
 - PREDICTED vs ACTUALS
- ATTITUDE CONTROL
 - CELESTIAL SENSOR INTENSITIES
 - GYRO DRIFTS
 - MOMENTUM WHEEL LOADING AND UNLOADING
- POWER
 - RTGs
 - BATTERIES

TREND ANALYSIS TOOLS

- SELECTION AND EDITING OF TLM DATA
- PROCESSED DATA DEFINITION
- PLOTTING
- STATISTICAL ANALYSIS
- LOCAL ARCHIVING
- REPORT GENERATION
- SCRIPTING TOOL
- AUTOMATED ANALYSIS PROCESSES



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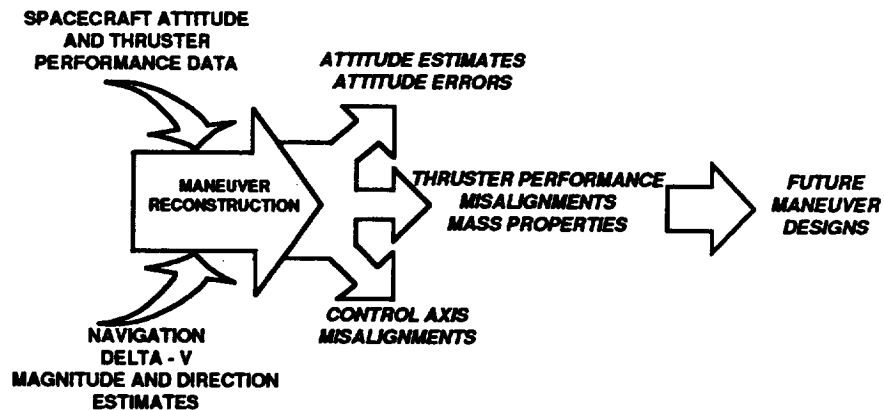
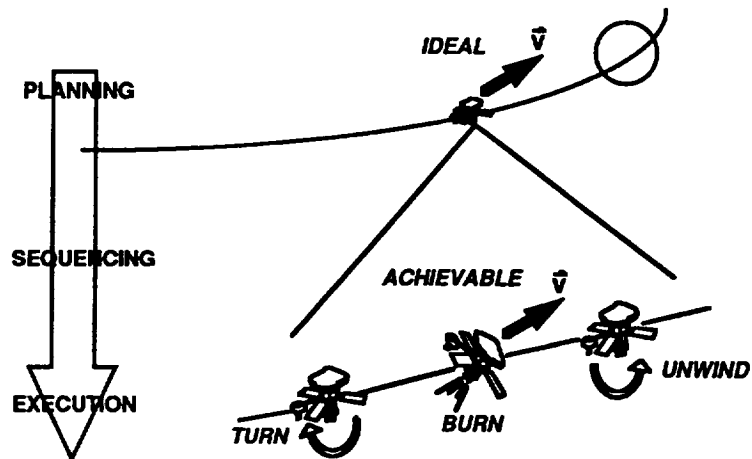
SPACECRAFT RESOURCE TRACKING AND MANAGEMENT

- SCIENCE INSTRUMENTS
 - MODE CHANGE CYCLES
 - FILTER WHEEL USAGE
- FUEL CONSUMPTION
- BATTERY DEPTH OF DISCHARGE CYCLES
- RTG AND SOLAR CELL POWER DEGRADATION
- LIFE TIME LIMITS ON
 - HARDWARE ON - OFF CYCLES
 - ACTUATOR TOTAL ANGLE OF TRAVEL
 - TAPE RECORDER TRACK USAGE
- MOMENTUM WHEEL SATURATION UNLOADING CYCLES



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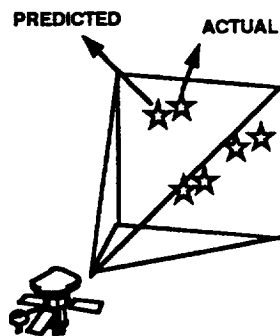


- INERTIAL REFERENCE UNITS (GYROS)
- ACCELEROMETERS
- CELESTIAL SENSORS
 - SUN SENSORS
 - STAR TRACKERS
 - HORIZON SENSORS
- HIGH GAIN ANTENNA POINTING
- PLATFORM POINTING
 - FIXED
 - ARTICULATING

BIAS
SCALE FACTORS
DRIFT

ELECTRO-
MECHANICAL
OFFSETS
MISALIGNMENTS

FUTURE
SCIENCE
SEQUENCES



ERROR MODEL
ESTIMATOR

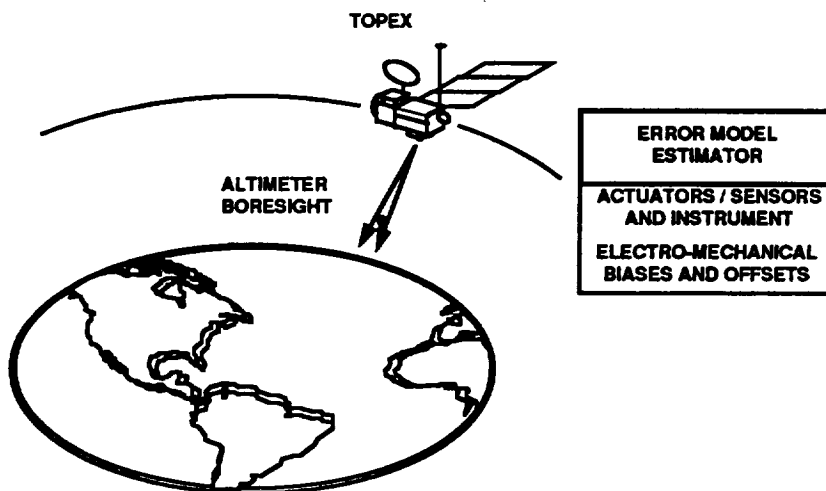
ACTUATORS AND
SENSORS

ELECTRO-MECHANICAL
BIASES AND OFFSETS

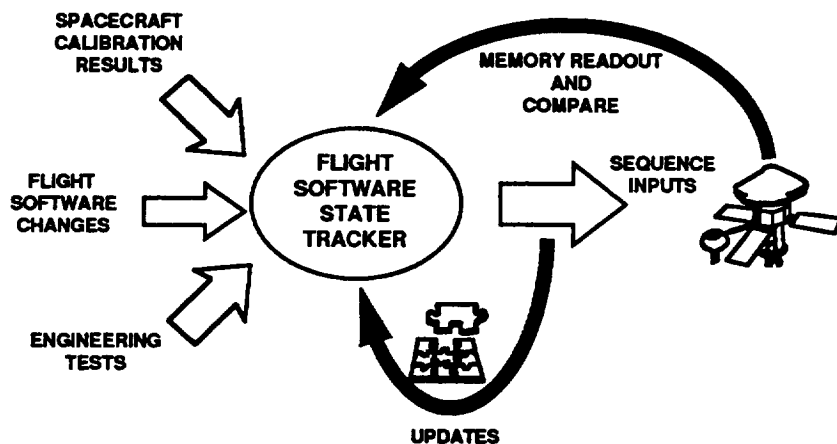
FUTURE
SCIENCE
SEQUENCES

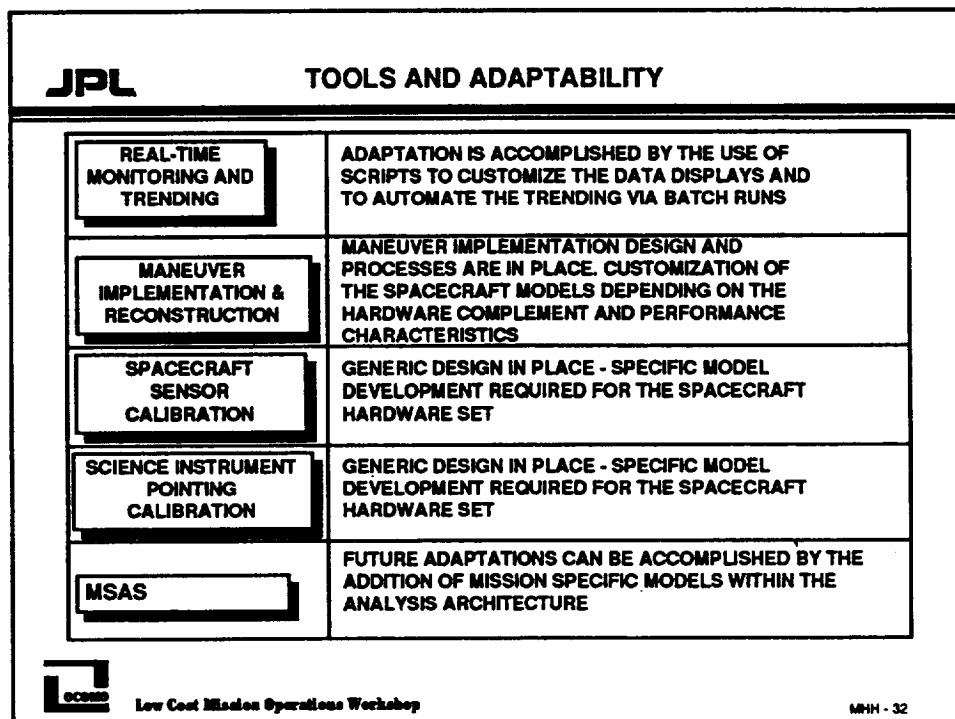
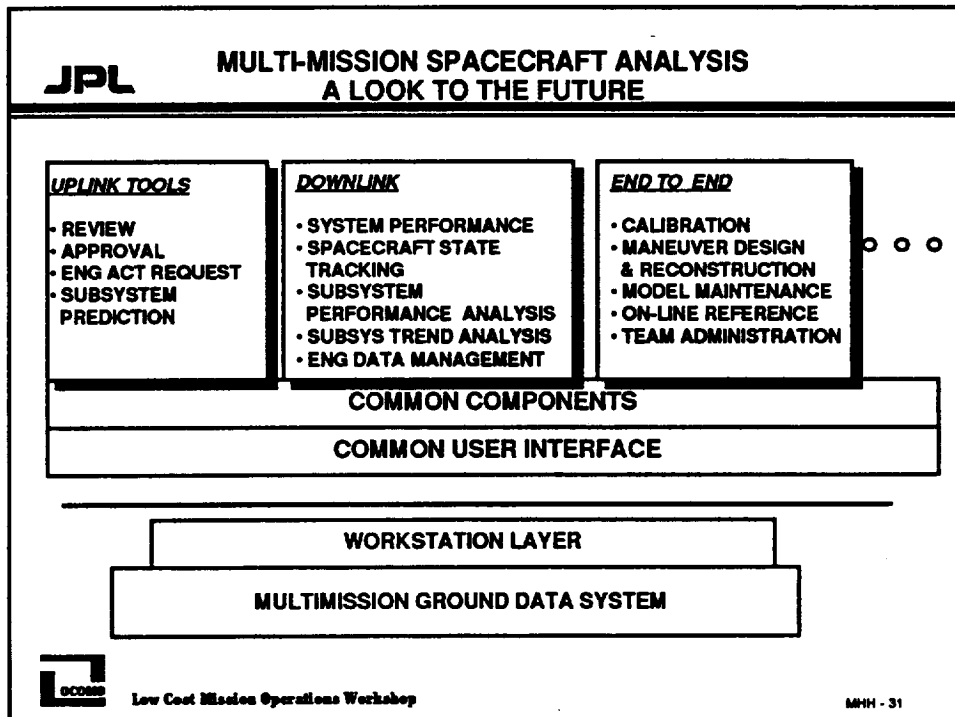


INSTRUMENT POINTING CALIBRATION NON-IMAGING



FLIGHT SOFTWARE MAINTENANCE PARAMETER UPDATES





REAL-TIME MONITORING AND TRENDING	<ul style="list-style-type: none"> • FLY WITH LARGE MARGINS • MONITOR A LIMITED SET OF SYSTEM TRENDS AND CONTROL THE SPACECRAFT AS A SYSTEM • MONITOR FOR ALARM VIOLATIONS ONLY
MANEUVER IMPLEMENTATION & RECONSTRUCTION	<ul style="list-style-type: none"> • RELAX PERFORMANCE REQUIREMENTS TO MINIMIZE THE AMOUNT OF RECONSTRUCTION REQUIRED • MOVE THE FUNCTIONS TO THE SPACECRAFT
SPACECRAFT SENSOR CALIBRATION	<ul style="list-style-type: none"> • RELAXED PERFORMANCE REQUIREMENTS REDUCES OR ELIMINATES THE NEED FOR CALIBRATIONS • MOVE SOME CALIBRATION FUNCTIONS TO THE SPACECRAFT
SCIENCE INSTRUMENT POINTING CALIBRATION	<ul style="list-style-type: none"> • RELAXED PERFORMANCE REQUIREMENTS REDUCES OR ELIMINATES THE NEED FOR CALIBRATIONS



NAVIGATION

- OPTICAL NAVIGATION
- REAL-TIME RADIOMETRIC MONITORING
- XMIRAGE : ORBIT DETERMINATION

SPACECRAFT ANALYSIS

- MISSION CONTROL ANALYSIS
- FLIGHT SOFTWARE MEMORY STATE TRACKER
- MARVEL: AUTOMATED TELEMETRY MONITORING SYSTEM
- VULCAN: SOLAR FLARE MODELING AND VISUALIZATION



- **MISSION COORDINATION IS HANDLED BY AN INSTITUTIONAL MISSION CONTROL TEAM**
 - CONFIGURATION AND CONTROL OF THE GROUND DATA LINKS TO AND FROM THE DSN
 - COMMANDING - PACKAGING & PROTOCOLS
 - REAL-TIME MONITORING
- **NAVIGATION**
 - RECOGNIZED SOURCE OF DATA FOR PLANETARY, SPACECRAFT, ASTEROID, AND COMET EPHEMERIDES
 - ORBIT DETERMINATION TOOLS
 - OPTICAL NAVIGATION AND RADIOMETRIC TRACKING
- **SPACECRAFT HEALTH AND MONITORING**
 - CORE SET OF TOOLS FOR REAL-TIME MONITORING AND TRENDING
 - MISSION-SPECIFIC TOOLS DEPEND ON SPACECRAFT HARDWARE CONFIGURATION AND DEVICES
 - HARDWARE CALIBRATION
 - INSTRUMENT POINTING CALIBRATION
 - ATTITUDE RECONSTRUCTION



Low Cost Mission Operations Workshop

SUMMARY

Gael F. Squibb

**Manager: Flight Projects Mission Operations
Development Program Office**



Low Cost Mission Operations Workshop

GFS - 1

OUTLINE

- ➔ • **ADDITIONAL SERVICES**
- **LOW COST CONSIDERATIONS**
- **MARS PATHFINDER DEVELOPMENT COSTS**
- **TECHNOLOGY**
- **A LOOK TO THE FUTURE**



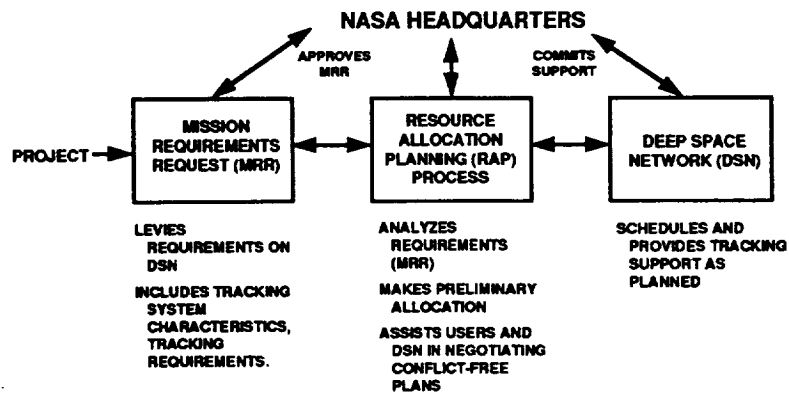
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GFS - 2

- **RESOURCE ALLOCATION PROCESS (RAP)**
- **TRAINING AND READINESS**
- **LAUNCH OPERATIONS SUPPORT**
- **END-TO-END INFORMATION SYSTEM (EEIS) ENGINEERING**



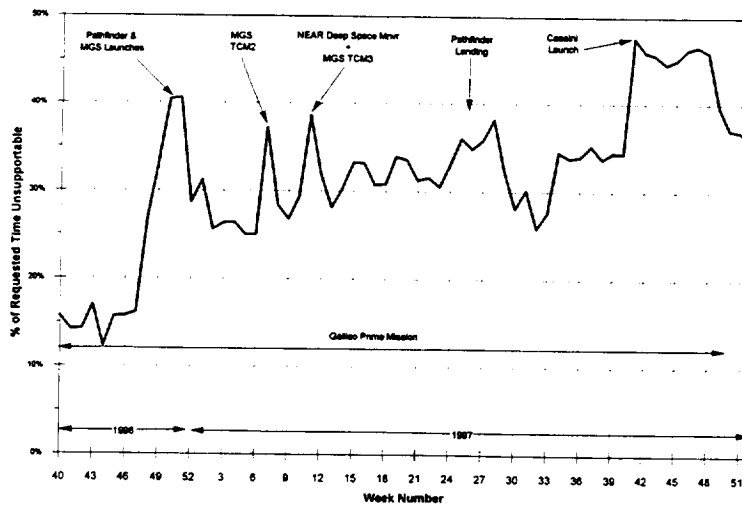
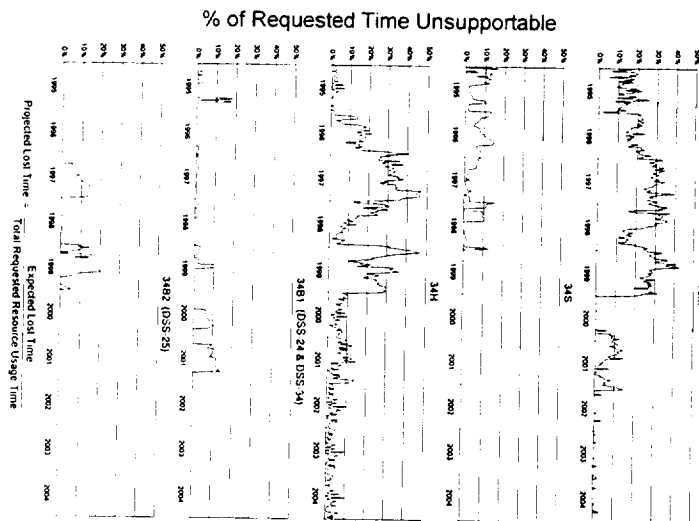
**RESOURCE ALLOCATION PLANNING PROCESS
FOR THE DEEP SPACE NETWORK**



ESSENTIAL TO UNDERSTAND THE PROCESS

THE SYSTEM IS ALMOST ALWAYS OVERSUBSCRIBED
 USERS MUST PLAN AHEAD
 CONFLICTS CAN BE RESOLVED WHEN IDENTIFIED EARLY
 FLEXIBILITY IS VITAL







ADDITIONAL SERVICES

MISSION OPERATIONS SYSTEM TRAINING & READINESS

- **GROUND DATA SYSTEM FAMILIARIZATION**
 - WORKBOOKS
 - LECTURES
- **WORKSTATION APPLICATION TRAINING**
 - BASIC WORKSTATION
 - POWER USER TOOLS
- **MISSION OPERATIONS POSITIONAL TRAINING AND CERTIFICATION**
- **PROJECT SCENARIO TRAINING EXERCISES**
 - FAULT RECOVERY EXERCISES
- **END-USER WORKSTATION SYSTEM CONFIGURATION AND USER CONSULTING**



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ADDITIONAL SERVICES

LAUNCH OPERATIONS SUPPORT

- **JPL RESIDENT OFFICE AT CAPE CANAVERAL PROVIDES:**
 - SAFETY TRAINING, BADGING, AND SECURITY ASSISTANCE
 - RECEIVING AND HANDLING OF SPACECRAFT AND SCIENCE INSTRUMENTS
 - HELP IN SCHEDULING USE OF EASTERN LAUNCH SITE FACILITIES
 - HELP IN PUBLICATION OF REQUIRED DOCUMENTATION
 - TECHNICAL SUPPORT FOR LAUNCH PREPARATION PROCESS
 - INTERFACE TO KENNEDY SPACE CENTER (KSC)
- **JPL PROVIDES TECHNICAL SUPPORT TO LAUNCH CAMPAIGN**
 - SPACECRAFT SYSTEM TEST OPERATIONS
 - SPACECRAFT LAUNCH ANOMALY TEAM
 - GROUND DATA SYSTEM OPERATIONS
 - INTERFACE TO JPL OPERATIONS CENTER



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ADDITIONAL SERVICES

END-TO-END INFORMATION SYSTEM ENGINEERING

- JPL HAS EXPERIENCED ENGINEERS TO ASSIST PROJECTS AND P.I.'s IN DESIGNING A COST-EFFECTIVE END-TO-END INFORMATION SYSTEM, WHICH INCLUDES GROUND AND FLIGHT COMPONENTS OF THE INFORMATION SYSTEM



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SERVICES

- PROJECT DESIGN CENTER (PDC)
- FLIGHT SYSTEM TESTBED (FST)



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- SERVICES
- ⇒ • LOW COST CONSIDERATIONS
 - MARS PATHFINDER DEVELOPMENT COSTS
 - TECHNOLOGY
 - A LOOK TO THE FUTURE



- FACTORS
 - COMPLEXITY OF THE MISSION
 - OPERABILITY OF THE SPACECRAFT AND INSTRUMENTS
 - DESIGN OF THE MISSION OPERATIONS SYSTEM
 - MANAGEMENT RISK POLICIES
- GROUND APPROACHES FOR A GIVEN FLIGHT SYSTEM
 - PERFORM FUNCTIONS MORE EFFICIENTLY
 - ELIMINATE FUNCTIONS AND CAPABILITIES
 - USE LOWER COST STAFF
 - ASSUME GREATER RISK

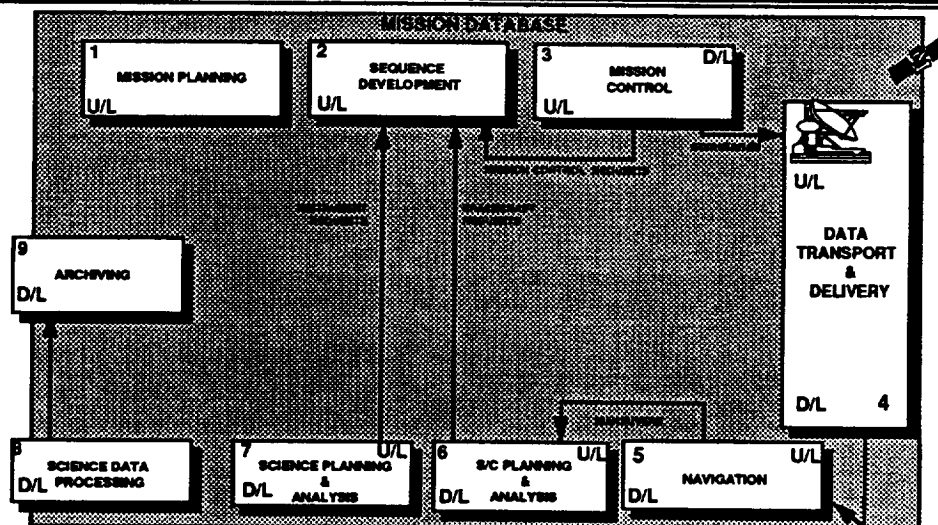


MISSION PLANNING AND ANALYSIS

- ENSURE THAT SPACECRAFT AND INSTRUMENTS HAVE POSITIVE MARGINS SO THAT SEQUENCES DO NOT HAVE TO BE VALIDATED FROM AN ENGINEERING POINT OF VIEW
- EXAMINE SPACECRAFT AUTONOMY VS GROUND SEQUENCING OF APPROPRIATE FUNCTIONS
- DESIGN THE MISSION AND SPACECRAFT TO MINIMIZE THE NUMBER OF MISSION AND FLIGHT RULES TO CHECK
- MAXIMIZE OPERABILITY AND ENSURE MINIMUM AMOUNT OF INTERACTION BETWEEN SUBSYSTEMS



SYSTEM OVERVIEW



SEQUENCE DEVELOPMENT

- **REDUCE THE NUMBER OF SEQUENCES THAT MUST BE PRODUCED**
- **ELECTRONIC REVIEW OF SEQUENCE**
- **SET APPROVAL LEVEL AT LOWEST POSSIBLE LEVEL:
WHAT IS THE VALUE ADDED BY THIS APPROVAL LEVEL?**
- **MINIMIZE SEQUENCE CHANGES DURING THE SEQUENCE
DEVELOPMENT PERIOD**
- **USE AN INTEGRATED SET OF SEQUENCING TOOLS
RATHER THAN MANY INDIVIDUAL TOOLS**

**SEQUENCE DEVELOPMENT (Continued)**

- **USE CONTINUOUS RUNNING SEQUENCE WITH TIME GAPS
FOR SEQUENCE OVERLAYS**
- **DEVELOP SEQUENCE DEVELOPMENT STRATEGY THAT
ELIMINATES CONFLICTS**
- **BLOCK TIMES FOR COMPATIBLE REQUESTS**
- **ADOPT A PRIORITY SCHEME THAT ALLOWS AUTOMATIC
RESOLUTION OF CONFLICTS**
- **USE REUSABLE BLOCKS**
- **PERFORM SEQUENCE VALIDATION OF FUNCTION WITH
ACCEPTABLE DATA-RETURN RISK**



MISSION CONTROL

- **SHARING OPERATORS BETWEEN MISSIONS**
- **MULTI-TASK OPERATORS WITH RELATED TASKS**
- **HAVE GROUND AND FLIGHT SYSTEMS THAT ACCOMMODATE CHANGE**
- **USE GRAPHICAL USER INTERFACES THAT REDUCE THE REQUIREMENTS ON THE MISSION CONTROLLERS FOR DETAILED GROUND OR FLIGHT KNOWLEDGE**
- **AUTOMATED ANALYSIS OF GROUND AND FLIGHT INFORMATION WHICH IDENTIFIES OR ANTICIPATES PROBLEM AREAS**

**DATA TRANSPORT AND DELIVERY**

- **MINIMIZE AMOUNT OF DSN COVERAGE REQUIRED**
- **DESIGN THE SPACECRAFT AND INSTRUMENT DATA CONTENT, STRUCTURES, AND FORMATS TO MATCH THE CAPABILITIES OF THE EXISTING TRANSPORT AND DELIVERY SYSTEMS**
 - **USE SPECIFIC STANDARDS TO ENSURE COMPATIBILITY OF SPACECRAFT DATA SYSTEM AND GROUND DATA SYSTEM**
- **USE VARIABLE LENGTH PACKETS, AS OPPOSED TO MANY SPECIFIC FORMATS**



NAVIGATION

- **UNDERSTAND ACCURACY REQUIREMENTS VS NAVIGATION COST**
- **MINIMIZE DEMANDS OF MANEUVER FREQUENCY**
 - **THREE MANEUVERS IN FIVE DAYS FOR EACH ORBIT WILL BE COSTLY**
- **UNDERSTAND DSN SERVICES (FREE) VS PROJECT-SPECIFIC FUNCTIONS AND ATTEMPT TO MINIMIZE PROJECT-SPECIFIC REQUIREMENTS**
- **TRADE OFF ONBOARD NAVIGATION FUNCTIONS VS GROUND-BASED FUNCTIONS ACCOMMODATED BY SEQUENCE DEVELOPMENT**

**SPACECRAFT PLANNING AND ANALYSIS**

- **DESIGN THE SPACECRAFT SO IT CAN BE ANALYZED AT THE SYSTEM LEVEL**
 - **ENSURE DIRECT MEASUREMENTS OF SYSTEM-LEVEL PARAMETERS**
- **MAINTAIN SUBSYSTEM MARGINS**
- **MINIMIZE INTERACTIONS**
- **HAVE ROBUST SAFING CAPABILITY**
- **MINIMIZE THE NEED FOR REAL-TIME ANALYSIS OF ENGINEERING DATA**
- **USE AUTOMATED ANALYSIS TOOLS**



SCIENCE PLANNING AND ANALYSIS

- **USE EXISTING PLANNING TOOLS**
- **CONSIDER COMBINING PLANNING AND ANALYSIS FUNCTIONS FOR SPACECRAFT AND SCIENCE INSTRUMENTS**
- **CONSIDER AUTOMATION OF INSTRUMENT DATA - GATHERING SEQUENCES**
- **DURING THE DESIGN PHASE, ASK THE QUESTION: HOW WILL I DETERMINE THE INSTRUMENT COMMANDS BASED ON SCIENTIFIC PARAMETERS FOR AN OBSERVATION?**
- **MINIMIZE THE NEED FOR SEQUENCES BASED ON DATA RECEIVED (ADAPTIVE OR NOT KNOWN)**

**SCIENCE DATA PROCESSING**

- **USE EXISTING TOOLS**
- **UNDERSTAND THE AVAILABILITY OF ANCILLARY DATA NEEDED FOR SCIENCE DATA PROCESSING**
- **UNDERSTAND ROBUSTNESS OF PROCESSING-TO-DATA-LOSS OR DROPOUTS. REQUIRES UNDERSTANDING OF THE DATA TRANSPORT PERFORMANCE RELATIVE TO SCIENCE DATA**
 - **COMPRESSION**
 - **FORMATTING**



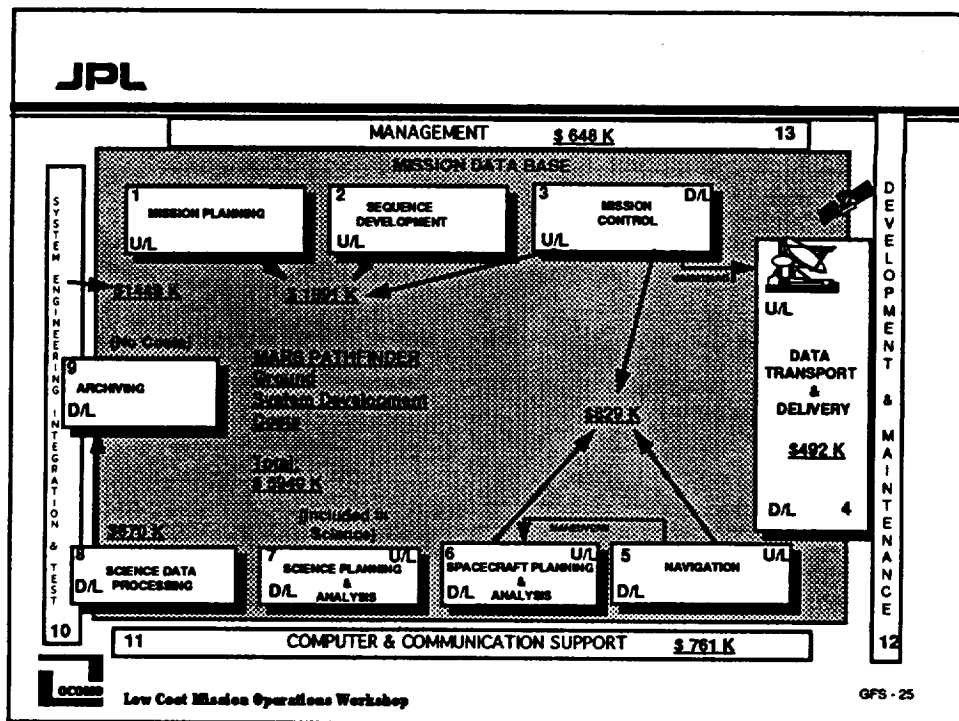
ARCHIVING

- **DEVELOP THE PLAN EARLY AND ENSURE THAT THE CAPABILITIES EXIST, RATHER THAN TRY TO PUT TOGETHER CAPABILITY TO MEET ARCHIVE REQUIREMENTS LATE**
 - **ANCILLARY DATA NEEDED**
 - **SUPPORTING DOCUMENTATION**

**MOS MANAGEMENT**

- **ASSIGN STAFF TO MULTIPLE TASKS**
- **USE GRADUATE STUDENTS FOR SOME FUNCTIONS**
- **KEEP OPERATIONS ORGANIZATION SIMPLE**
- **MINIMIZE INTERFACES BETWEEN GROUPS**
 - **LOOK AT RECEIVABLES AND DELIVERABLES FOR EACH GROUP**
- **ESTABLISH COST-EFFECTIVE RISK-AVOIDANCE POLICIES**





JPL **OPERATIONS ORGANIZATIONS**

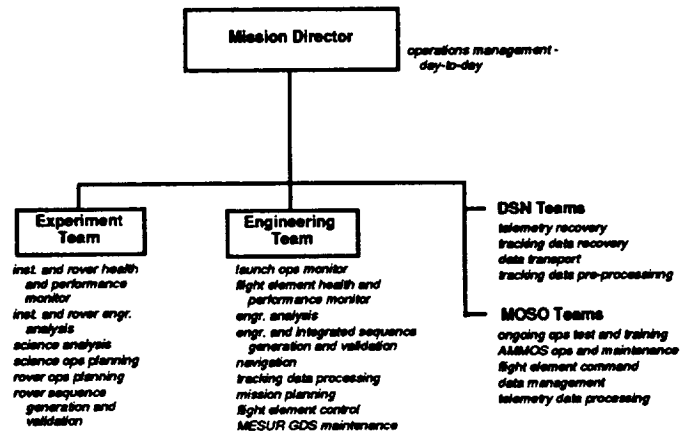
- THE FOLLOWING PROJECTS ARE OPERATING WITH SPECIFIC COST CONSTRAINTS AND HAVE TRADED OFF CAPABILITIES AND SCIENCE RETURN VS COST
 - MARS PATHFINDER
 - VOYAGER:
 - EXTENDED MISSION
 - PLUTO
- MOST EARLY PLANETARY MISSIONS WERE OPERATED UNDER A PERFORMANCE PARADIGM, AND WERE NOT DESIGNED TO MINIMIZE OPERATIONAL AND LIFE CYCLE COSTS

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JPL MARS PATHFINDER OPERATIONS ORGANIZATION

with Operations Functional Assignments

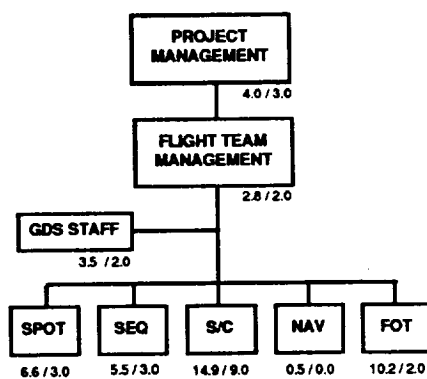


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JPL VOYAGER FLIGHT TEAM ORGANIZATION CHANGES

FUNCTION-ORIENTED ORGANIZATION

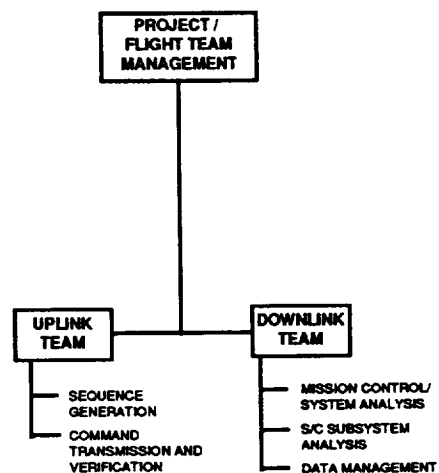


NOTE: Staffing numbers reflect 1993 staffing / 1995 staffing - (48.0/24.0)



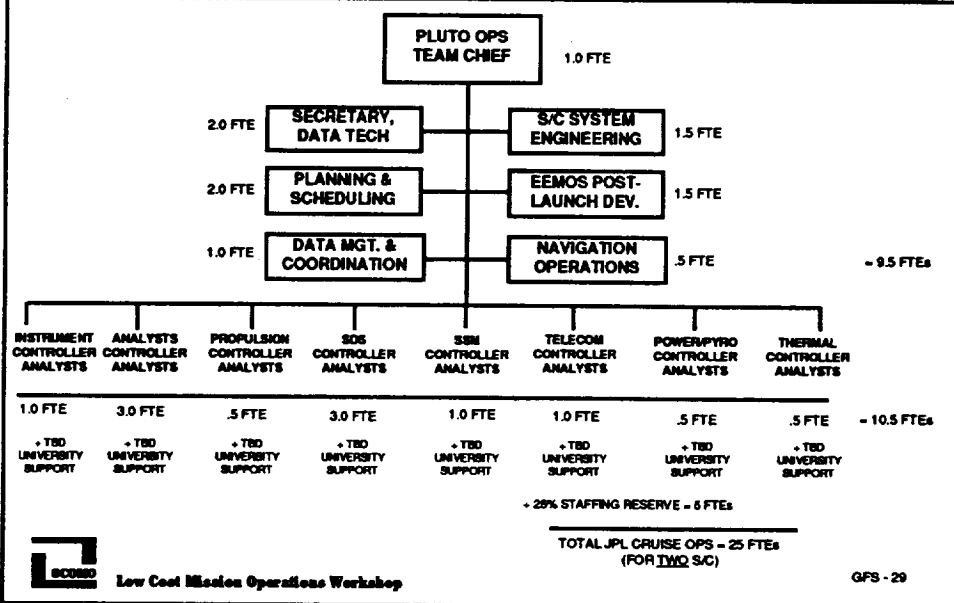
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PROCESS-ORIENTED ORGANIZATION



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PLUTO CRUISE OPERATIONS



SUMMARY OUTLINE

- SERVICES
- LOW COST CONSIDERATIONS
- MARS PATHFINDER DEVELOPMENT COSTS
- ➔ • TECHNOLOGY
- A LOOK TO THE FUTURE

- **SPACECRAFT TECHNOLOGY TO ENABLE LOWER COST OPERATIONS**
 - MARGINS
 - LARGER MEMORIES AND FASTER CPU's
 - SOLID STATE MEMORIES AND ONBOARD DATA MANAGEMENT
- **SPACECRAFT CONTROL AND SEQUENCING**
 - EVENT-DRIVEN SEQUENCING
 - ONBOARD MANEUVER COMPUTATION
 - PROCESS CONTROL (RULE-BASED SEQUENCES)
 - UPLINK SERVICE SPECIFICATION
 - STANDARDIZED DATA COLLECTION, RETRIEVAL, STORAGE, AND TRANSPORT



- **MICRO-SPACECRAFT TECHNOLOGY MUST ENSURE THAT SPACECRAFT USING THESE TECHNOLOGIES HAVE SIGNIFICANTLY GREATER MARGIN THAN THE CURRENT GENERATION OF SPACECRAFT, ESPECIALLY IN THE FOLLOWING AREAS:**
 - POWER
 - THERMAL
 - TELECOMMUNICATIONS
 - DATA STORAGE
 - COMPUTATIONAL SPEED



- **LARGER MEMORIES AND FASTER CPU'S WILL ENABLE USE OF**
 - **STANDARD OPERATING SYSTEMS**
 - **MODERN PROGRAMMING LANGUAGES**
 - **SPACECRAFT AUTONOMY TO REDUCE MISSION OPERATIONS COSTS**
 - **HIGHER LEVEL SEQUENCE LANGUAGES ONBOARD**
 - **HIGHER LEVEL SIMULATIONS (IF REQUIRED), SINCE ADEQUATE MARGINS WILL ELIMINATE NEED FOR MICRO-SECOND SIMULATIONS**



- **DSN OVERLOADING WILL REQUIRE SHORTER TRACKS, WHICH WILL DRIVE THE NEED FOR LARGER SOLID-STATE RECORDERS**
- **EASY DATA MANAGEMENT OF THESE RECORDERS (PC-LIKE EASE) MUST BE INCLUDED TO KEEP OPERATIONAL COSTS DOWN**
 - **RECORDER MODELING OF DATA LOCATION IS COST-PROHIBITIVE**
- **SHORTER DSN TRACKS WILL ALSO DRIVE THE NEED FOR HIGHER DATA TRANSMISSION RATES FOR THE OUTER PLANETARY MISSIONS**
- **JOINT SPACECRAFT AND DSN TECHNOLOGY THRUSTS ARE REQUIRED**





MOS TECHNOLOGY SPACECRAFT CONTROL AND SEQUENCING

- **EVENT-DRIVEN SEQUENCING**
 - REQUIRED FOR MISSIONS SUCH AS ASTEROID SAMPLE
 - NASA HAS LITTLE EXPERIENCE IN THIS TYPE OF SEQUENCING BECAUSE WE HAVE DEVELOPED SEQUENCES IN THE TIME DOMAIN BOTH FOR PLANETARY AND ASTROPHYSICS MISSIONS
- **ONBOARD COMPUTATION OF MANEUVERS**
 - MORE COMPUTER POWER MAY ALLOW ONBOARD OPTICAL NAVIGATION WHICH COULD BE REQUIRED FOR SOME MISSIONS
- **UPLINK PROCESS CONTROL**
 - APPLY RESULTS OF PROCESS CONTROL RESEARCH TO SPACECRAFT CONTROL
 - RULE-BASED SEQUENCING
 - CLEMENTINE IS USING FIRST SUCH SPACECRAFT AND GROUND S/W
 - NEED TO VALIDATE NEW RULES ON GROUND BEFORE SENDING RULES TO SPACECRAFT
 - IMPLIES COMMON GROUND AND SPACECRAFT SHELL FOR PROCESS CONTROL



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MOS TECHNOLOGY SPACECRAFT CONTROL & SEQUENCING

- **UPLINK SERVICE SPECIFICATIONS**
 - THE DOWNLINK SERVICE SPECIFICATION (CCSDS) HAS ENABLED STANDARDIZATION OF TRANSPORT AND PROCESSING OF SPACECRAFT DATA
 - AN UPLINK SERVICE SPECIFICATION WILL ENABLE THE STANDARDIZED CONTROL OF SPACECRAFT WHICH FOLLOW THE STANDARD (FROM A DATA SYSTEM POINT OF VIEW)
 - WORK HAS JUST STARTED BUT NEEDS TO BE ESCALATED IN IMPORTANCE & FUNDING
- **STANDARDIZED DATA COLLECTION, RETRIEVAL, STORAGE, AND TRANSPORT**
 - THIS FUNCTION IS THE SAME FOR ALL MISSIONS
 - WE RE-IMPLEMENT IT FOR EACH NEW PROJECT
 - WITH LARGER, FASTER COMPUTERS AND USE OF MODERN PROGRAMMING LANGUAGES, WE NEED TO DEVELOP THE SOFTWARE FOR THIS CAPABILITY THAT WILL WORK ACROSS SEVERAL SPACECRAFT COMPUTER PLATFORMS AND BE COMPATIBLE WITH CURRENT GROUND SYSTEMS



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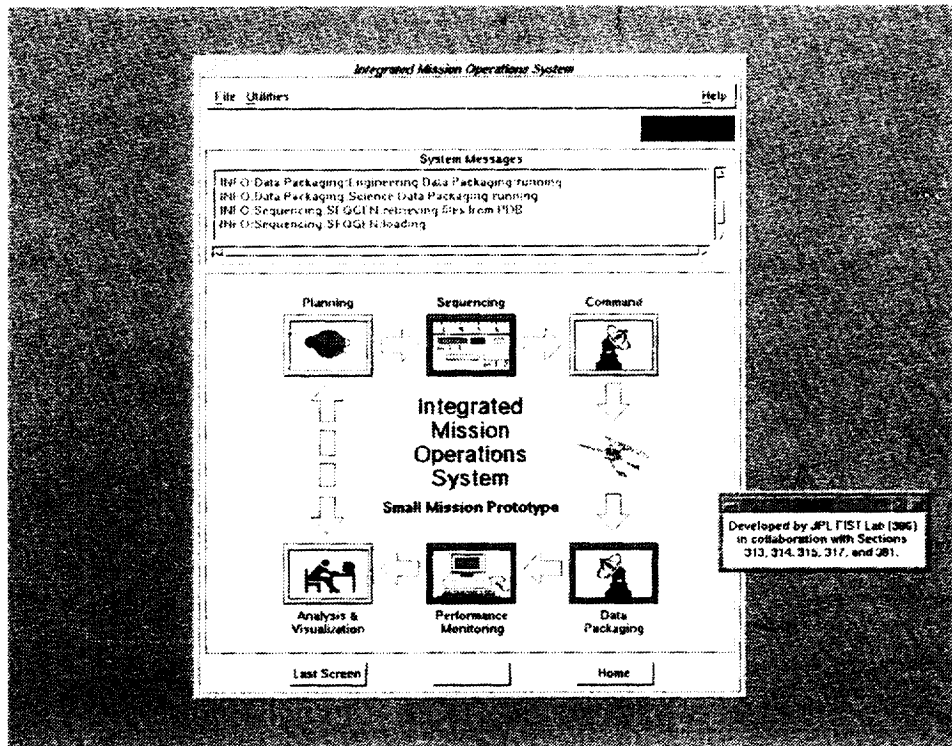
- **MISSIONS THAT SPEND THE PROJECT MONEY ON NEW INSTRUMENTS AND PROCESSING OF DATA AS OPPOSED TO RE-IMPLEMENTING DATA FUNCTIONS AGAIN**
- **INCORPORATION OF NEW CAPABILITIES INTO AN INTEGRATED SET OF TOOLS THAT ARE EASY TO USE BY ANY PERSON PARTICIPATING IN OPERATIONS**
- **CROSS-TRAINING INDIVIDUALS, AS OPPOSED TO CREATING A MULTITUDE OF SPECIALISTS**



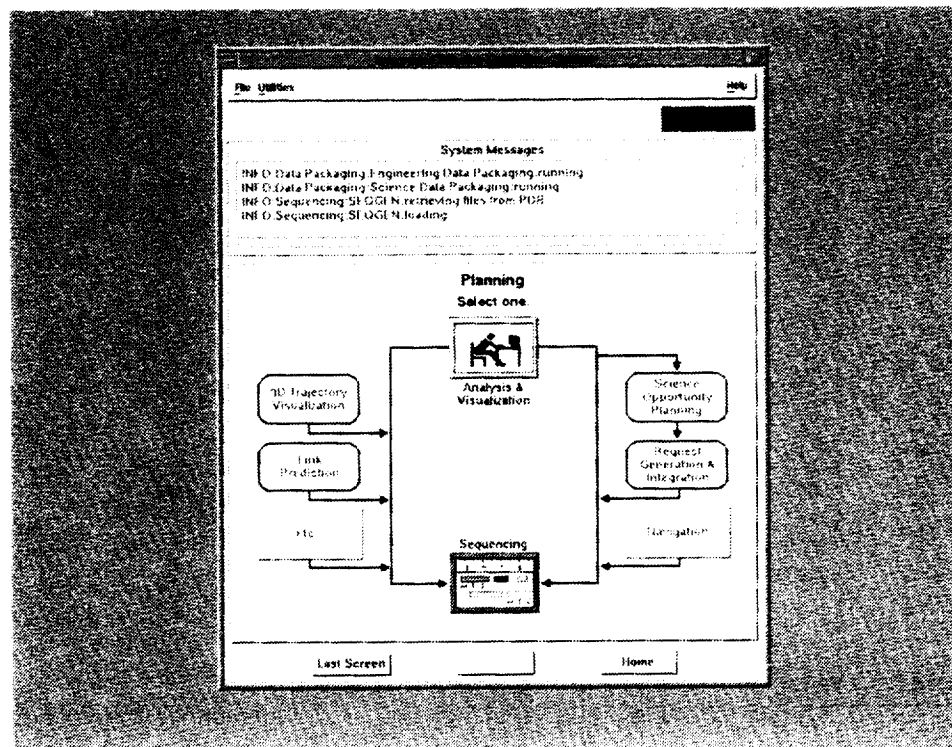
SEVERAL POSSIBLE WAYS TO INTERACT WITH US AFTER THIS WORKSHOP

- **UNSOLICITED PROPOSAL**
- **LETTER OF INTEREST**
- **DESCRIBE SOURCES OF MORE COST-EFFECTIVE CAPABILITIES OR APPROACHES**
- **GIVE INFORMATION ABOUT CAPABILITIES WE SHOULD BE AWARE OF PRIOR TO ENTERING INTO FURTHER DIALOG**
- **DEMONSTRATION OF EXISTING CAPABILITIES THAT WOULD OFFER COST SAVINGS TO NASA**





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Panelists

Tuesday, April 5

Michael Ebersole
Norman R. Haynes
William Kurth
T.D. Linick
Gael Squibb

Wednesday, April 6

Esker K. Davis
Ray Goldstein
Norman R. Haynes
William Kurth
T.D. Linick
Gael Squibb

Tuesday, April 7

John Casani
Norman R. Haynes
Ed Kieckhefer
T.D. Linick
Steve Proia
Gael Squibb

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Panelists

<i>Name</i>	<i>Affiliation</i>	<i>Title</i>	<i>Organization</i>
Casani, John R.	JPL	Assistant Laboratory Director	Office of Flight Projects
Davis, Esker K.	JPL	Manager	Discovery Office
Ebersole, Michael M.	JPL	Assistant Manager	Mars Pathfinder Project
Goldstein, Dr. Raymond	JPL	Manager	Space Physics & Astrophysics
Haynes, Norm R.	JPL	Assistant Laboratory Director	Telecommunications & Data Acquisition
Kieckhefer, Edward H.	JPL	Contract Negotiation Specialist	Procurement
Kurth, Willam S.	University of Iowa	Consultant	Advanced Information Systems
Linick, T.D.	JPL	Manager	Multimission Operations Systems Office
Proia, Stephen L.	JPL	Manager	NASA Prime Contract Section
Squibb, Gael F.	JPL	Manager	Mission Operations Development Program Office

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Demonstrations

1. Science Data Processing and Analysis

AESOP - Advanced End-to-End Simulation of Onboard Processing
VICAR - Instrument Data Processing Software
LinkWinds - Science Analysis Support System
PLATO - Processing and Display of Image Data from PDS Data Sets
DBVIEW - Science Data Management System Client Software

2. Mission Design, Planning and Sequencing

SEQ_POINTER - Remote Sensing Observation Generation and Design
PLAN-IT-II - Activity Generation and Integration
SEQ_GEN - Sequence Generation and Integration
SEG Shell and SEG - Sequence of Events Generator and its Operational Shell
Command Translation Tool Kit - Command Mnemonic, Bit Pattern, and
Corresponding Telemetry

3. Data Transport and Delivery

Telemetry Data Processing Demonstration
Data Query Demonstration
Mars Pathfinder Demonstration

4. Mission Coordination and Engineering

Navigation
Optical Navigation
Real-Time (Radiometric) Monitoring
XMIRAGE - Orbit Determination Software

Spacecraft Analysis
Flight Software Memory State Track
Mission Control Analysis
MARVEL
VULCAN

5. Summary

IMOS - Integration Mission Operations System
Small Mission Prototype

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For More Information

If you would like more information about low cost mission operations at JPL, you may contact these people:

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Esker K. Davis

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Al Beers

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Ray Amorose

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